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# TORNADOES, WHAT THEY ARE,

AND

## How to Escape Them.

FINLEY.

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# TORNADOES, WHAT THEY ARE,

—AND—

## How to Escape Them.

—BY—

*JOHN P. FINLEY,*
*Lieutenant Signal Corps, U. S. Army.*

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## The Following Publications Have Been Consulted in the Preparation of this Manual:

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# PREFACE.

There is a growing and unfailing interest in the subject of tornadoes, both for commercial and scientific reasons. From a theoretical standpoint, the field is a large one and peculiarly important, owing to the singular formation and appearance of the storm, its extraordinary violence, and its typical character, as distinguishing the *local* from the *general* and *secondary* motions of the atmosphere.

From a practical point of view the tornado seriously affects the most precious of human interests, and naturally a most persistent struggle is made to overcome such unfortunate results.

The public is ever ready to receive information concerning this remarkable and extremely interesting meteorological phenomenon, and it is the purpose of this small manual to place in the hands of the people an epitome of the United States Signal Service records to date, together with a brief, practical discussion of the origin of tornadoes, and the best means, so far as the writer can determine, of securing protection for both life and property.

As the country grows, the danger thickens apace, and preparation should be made accordingly. But this readiness does not involve, as some have conjectured, extraordinary expenditure or difficult research.

The mystery of the tornado cloud has been swept away as the result of prolonged and thorough investigation. In

spite of its extraordinary and unprecedented violence, and the peculiarity of its formation and movements, means of escaping its fury have been devised and applied with success.

Life can be saved and property can be protected, the former by the tornado cave and the latter by legitimate insurance.

Life is worth any effort to save and protect it, and even though the danger is averted for a time, readiness in this case never more forcibly exhibited the truth of the old adage "an ounce of prevention is better than a pound of cure."

This volume is too contracted to treat the subject exhaustively, and such a discussion was not intended, but it is hoped that the practically important features are set forth with sufficient force and clearness to make the truth apparent to the ordinary reader, and to impress upon his mind the necessity of observing certain precautions. The tornado may not strike you to-day, but one day too late in making the necessary preparations, may cause the work of a lifetime to disappear in the darkness of the tornado's terrible maelstrom.

THE AUTHOR.

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# *TORNADOES, WHAT THEY ARE,*

—AND—

# How to Escape Them.

## THE WEATHER.

From the earliest times more or less interest has been manifested by the people of all nations in the phenomena of the atmosphere.

Every village has its weather-seer who deals in prognostics, and carefully observes and records important meteorological events.

As we advance in civilization and material prosperity, the necessity for a thorough and practical knowledge of the weather is apparent.

It is a very easy matter to cite instances where hundreds, thousands, and in some cases, where millions of dollars have been saved by the timely warnings of approaching changes in the weather.

These benefits extend not only to property but to life as well.

The practical relation of meteorology to agriculture and commerce is no longer a mooted question.

The evidence of its usefulness is growing daily, and thousands reap the benefits now where scores did a few years ago.

The value of the meteorological information here referred to relates more particularly to the daily changes of the weather. Farmers, physicians, mechanics, fruit-growers, pork-packers, fish and oyster dealers, coal-dealers, river-boatmen, and others engaged in various industries, are interested in knowing when sudden changes in temperature are likely to occur, whether it is to rain or shine, the direction and force of the wind, the percentage of moisture in the air, and the range of temperature.

The shipping interests of the Lakes, and of the Gulf and Atlantic coasts, are protected by the knowledge which they obtain, through the prognostications of the United States Weather Bureau, of the direction of movement and force of storms. But these are phenomena that people must make every-day provision for. Cold and heat, frost and snow, unfavorable winds and variable humidity, constantly attend the never ceasing "roll and billow" of the boundless atmospheric sea.

## THE TORNADO.

A few years ago the country was rudely awakened from a "Rip Van Winkle sleep" by the awful roar and unparalleled violence of that demon of the air, the dreaded tornado.

Many people living in the sections of country laid waste along the track of this monster thought the millenium at hand, others wondered what manner of thing it was, so strange its movements, so irresistible its power. Some queried if the Almighty was not thus punishing man for his wickedness.

To those acquainted with the motions of the atmosphere and the dynamic effect of solar heat upon it, these reasonings seem very ludicrous indeed.

The tornadic disturbance is as old as the world itself, if we are to believe that the appearance of the atmosphere was coincident with the creation of the earth.

The tornado has always been with us, but so many have escaped its terrors because of widely separated homes in a newly settled country, that to thousands such a storm was long unknown.

How different are the facts to-day. Who has not heard of the dark whirling cloud which leaves death and destruction in its wake?

How many can speak of the most thrilling experiences, hair-breadth escapes, black desolation and frightful sufferings? What horrors rise up before you at the long list of places where entire villages have been swept from the earth.

Who that has read of or witnessed the shocking scenes of death and desolation in the tornado's wake will forget Grinnell, Iowa; Mt. Vernon, Illinois; St. Cloud, New Ulm and Rochester, Minnesota; Irving and Prescott, Kansas; Viroqua, Mineral Point and Racine, Wisconsin; Savoy, Texas; Richmond, Marshfield and Brownsville, Missouri; Jamestown and Washington Court House, Ohio; Wallingford, Connecticut; Ercildoun, Pennsylvania; Beauregard and Wesson, Mississippi; Tuscumbia and Auburn, Alabama; Rockingham and Wadesborough, North Carolina; Monticello and Cumming, Georgia; Darlington and Walterborough, South Carolina; Camden and New Brunswick,

New Jersey; North Vernon and Connersville, Indiana; the list might be extended to include hundreds of p where the tornado has left its indelible mark.

Is there any wonder at the avidity with which people any information on this all-absorbing subject?

If the usual phenomena of daily atmospheric variations excites public attention and appreciation, what should be expected regarding the most extraordinary manifestations of power that involve, not only the property but the lives of hundreds of people.

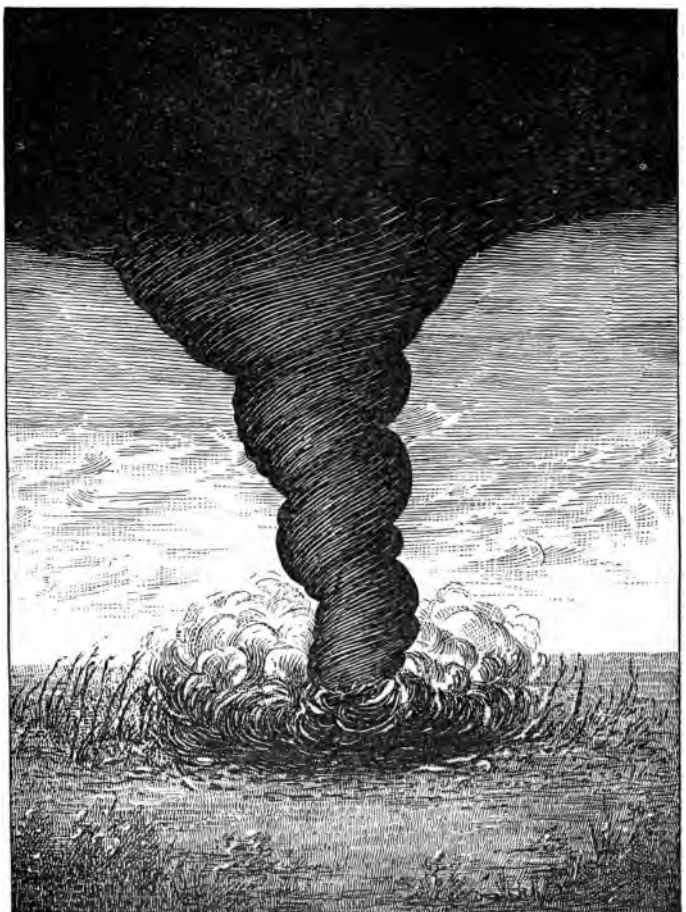
The public must be truthfully informed and given every opportunity for the preservation of life and property.

When such great questions are at stake and man's very existence is held in the balance against the price of protection, no effort or expense should be spared to obtain any adequate means that may be offered.

It is hardly necessary to say that this course is generally adopted, but unfortunately, in many cases, attended with much indifference and the exercise of bad judgment in the selection of proper means for the accomplishment of the desired result.

False premises lead to wrong conclusions and dangerous constructions.

It is the purpose of this little manual, while directing attention to the great dangers of the tornado, to also sweep away false notions regarding its origin and make known what is believed to be the most practical, trustworthy and economical methods of protecting both life and property.



THE TORNADO OF OSAGE COUNTY, KANSAS, JUNE 12TH, 1881; 3 PERSONS KILLED, 30 WOUNDED AND 53 BUILDINGS DESTROYED; LOSS, $150,000.

## DERIVATION OF TERM.

Let us first learn something of the origin of the term tornado, the character of this storm in other countries and what is essentially the cause of the phenomena. With right premises we are certain of safe conclusions and successful efforts.

We have before us a subject that, from the earliest times, has given rise to much discussion, puzzled many minds and enticed not a few to engage in earnest and laborious, but futile efforts, to discover the origin and explain the strange and terrible manifestations of the tornado's power.

How did we acquire the name? What did the term mean when first employed to designate an atmospheric phenomena, and has it the same signification now?

The Latin word is *tornare,* to turn, or in other words, a whirling wind. The Spanish and Portuguese word is *tornada,* which means to return or turn upon itself.

The Portuguese also employed the term *tranado,* or variable wind, that is, a wind appearing to come *at once* from all directions.

The Greeks very significantly applied the term *ecnephias,* meaning a wind of great force, caused by the meeting and bursting of clouds. They also referred to the tornado as a "small cloud in the air spread like a blanket over the top of a mountain." In this use of a word to define the storm, the Greeks were aiming at the employment of a term that would indicate and give expression to the peculiar form of the tornado cloud, "out of which came such awful noises

and violence, causing the earth to quake and all life to tremble with fear."

With all people, the effort seemed to be directed to the coinage of a word that would convey a description of a small whirling, cylindrical cloud, accompanied with much violence.

The word *tornado* then, has no uncertain derivation. About three centuries ago it possessed practically the same meaning that it has to-day. The word essentially defines the storm and the latter closely adheres to the term, through well known and invariable characteristics.

The signification of the Greek and Latin terms, and the Spanish and Portuguese, readily conform to the observed facts as they are known to exist in the development of the American tornado.

We have the small, dark cloud suddenly rising above the horizon, moving outward with tempestous force and whirling about a central vertical axis with inconceivable velocity.

It is not to be inferred from what has been said concerning the derivation of the word, that this storm was first observed in Greece, Spain and Portugal, on the contrary, the earliest records relate to what has been termed the "African tornado."

The Spanish and Portuguese sailors frequently experienced these storms with very severe loss, on the northwest coast of Africa. It is recorded of the Portuguese, that during one of their voyages of discovery to the West Indies, in the 15th century, their fleet of twelve sail, lost nine vessels, utterly destroyed by the "prodigious impetuosity of these sudden and awful guests." Over 200 years ago, the British seamen

reported their experience of "tornadoes" off the northwest coast of Africa, from the tenth to the twelfth degree of north latitude.

Their description of the storm appears as follows: "The fatal cloud rises as only a small spot in the air, and then displays itself, spreading like a carpet over the top of the mountain, which the seamen espying through the calmest weather, immediately furl their sails and provide for the ensuing storm, that not long after descends in winds and lightnings, being the more terrible because it begins with utmost fury at first, and the changes of the points, sudden as the twinkling of an eye. You shall have a treacherous calm, a dreadful tempest, and in a short space the sky is clear again and the sea as smooth as glass."

From the experiences of these early seamen on the northwest coast of Africa, we trace the use of the word tornado to England, and thence to the English Colonies in America.

As early as 1682, we find the record of a tornado at New Haven, Conn., June 10th, at 2.30 p. m. It was so called, and a minute and very interesting description was prepared and preserved of its peculiar features, which reads as if the storm occurred but yesterday. The same may be said of a tornado which occurred near Charleston, S. C., at 2 p. m. on the 4th of May, 1762, and described as a "terrible phenomenon resembling a large column of smoke and vapor rushing over the earth with prodigious velocity, destroying everything in its path."

From this early period to the present time, the word tornado has been applied to designate a small cylindrical

cloud with violent rotary motion, narrow path and enormously destructive power.

From what has now been said, there should be no further hesitation in the specific use of the word *tornado*. Recent discussions in scientific journals, the confusion and annoyance of the public, the varied and grotesque appellations used by the press, point to the necessity of employing a distinct and well defined term.

It is a matter of considerable importance in both practical and theoretical meteorology that phenomena, easily distinguishable by characteristics and invariable features, should be designated by appropriate terms. I refer to the several kinds of atmospheric disturbances collectively called storms, but individually termed cyclones, tornadoes, whirlwinds, waterspouts, hailstorms, and thunderstorms. Practically, they are separate phenomena. If we care to go back far enough, and theoretically consider the question of origin, we find that the source of all atmospheric changes is the sun's heat. Solar heat is the controlling influence which disturbs the atmosphere, producing all the great air movements over the face of the globe.

Says Prof. Langley in his "Researches of Solar Heat:" "If the observation of the amount of heat the sun sends the earth is among the most important and difficult in astronomical physics, it may be termed the fundamental problem of meteorology, nearly all whose phenomena would become predictable, if we knew both the original quantity and kind of this heat; how it affects the constituents of the atmosphere on its passage earthward; how much of it reaches the soil;

how, through the aid of the atmosphere, it maintains the surface temperature of this planet; and how, in diminished quantity and altered kind, it is finally returned to outer space."

## THE DEVELOPMENT OF ATMOSPHERIC DISTURBANCES GENERALLY KNOWN AS STORMS.

If all parts of the atmosphere had the same temperature and the same hygrometric state, then all the forces of gravity and of pressure which act upon any or all parts of it, would be everywhere the same. The entire atmosphere would assume the state of static equilibrium and for ever remain at rest.

Our atmosphere has not everywhere the same specific gravity, and is not homogeneous. On the contrary, it is an exceedingly rare and elastic body extending with diminishing density to an unknown distance into space, and pressing upon the earth with a force equivalent to the pressure of a homogeneous atmosphere five and a half miles high.

The atmosphere is not at rest, but constantly in motion. As some parts of the earth are much warmer than others and air expands and becomes rare as its temperature increases, its specific gravity is not the same in all parts of the earth, and therefore the equilibrium is destroyed, and a system of winds is produced.

Again we assume, that if the atmosphere had the same density in all parts of the earth, every portion of it would be in a state of static equilibrium, and its surface and the strata of equal density would assume the eliptical figure of the

earth's surface, and consequently the pressure of the atm
phere at the earth's surface would be everywhere the sar

Upon examination, however, we find that the temperati
of the atmosphere is less, and consequently its density great
in the polar than in the equatorial regions, and theref
the greater pressure of the polar regions causes the surf
of the atmosphere and the strata of equal density in
equatorial regions to rise a little above the level of equ
brium. The effect of this polar influence is to cause
atmosphere in the upper regions over the equator to fl
towards the poles, while the greater pressure of the po
regions produces a counter current towards the equator, n
the earth's surface, which would extend entirely down to
earth's surface were it not for the modifying causes arisi
from friction.

The earth and its envelope are so co-related, that sta
equilibrium of the atmosphere is an impossibility.

## MOTIONS OF THE ATMOSPHERE.

The motions of the atmosphere may be classified as gener
secondary and local.

The *General Motions,* are those which are produced b
difference of specific gravity in the atmosphere between t
equator and the poles. These motions give rise to a gene
but not violent disturbance of atmospheric equilibrium.

Before proceeding to the next class of motions, we m
briefly consider the character and effect of the general n
tions. As stated elsewhere, if the entire atmosphere h
the same temperature throughout and the same hygromet

state, it would remain in a state of static equilibrium. Under such circumstances, storms could not occur. Nature has not thus ordained in her economy, but regulates the distribution and uses of parts with better adaption to the ultimate accomplishment of every good.

Static equilibrium of the atmosphere is not maintained anywhere on the face of the globe. The tendency to equilibrium is constantly disturbed by the differences of temperature between the equatorial and polar regions, which gives rise to an interchanging motion of the air, towards the equator below, and from it above. Now were it not for the effect of the earth's rotation on its axis, this alternate motion of northerly and southerly air currents would continue in the direction of the meridian at all places.

## MECHANICAL EFFECTS.

We find there are certain forces concerned in producing the general motions of the atmosphere. They are essentially fundamental. We may call the FIRST force, that which is generated from the invariable tendency of the atmosphere to flow to places of lower level whenever it has from any cause forced itself above the general level of the surrounding air.

The SECOND force is known as the deflecting force, due to the earth's rotation upon its axis.

Whenever a particle of air has, from any cause, been put in motion towards the *north*, the blending of this motion with the rotary motion of the earth, produces a third force which causes a deflection of the general motion towards the *east*.

If the particles of air move towards the *south*, the combination of their motion with the rotary motion of the earth gives rise to a deflective force towards the *west*.

The THIRD force is that which results from a combination of a relative east or west motion of the atmosphere with the rotary motion of the earth. The joint effect of these two motions is to pile up the atmosphere at certain latitudes and diminish it at others, which gives rise to a disturbing force that prevents the atmosphere from assuming a state of equilibrium.

There is necessarily produced differences of atmospheric pressure at these latitudes which in a general way affect all air movements.

## THE EARTH'S AXIAL ROTATION.

The effect of the earth's rotation upon extensive centripetal and contrifugal motions of the atmosphere is to give rise to a deflecting force, to the *right* of the direction of the moving body in the northern hemisphere, and to the *contrary* in the southern, no matter what the direction of motion. From this state of things, it will be seen that air moving above, toward the poles, is deflected towards the east, but to the west when flowing towards the equator below.

The deflective force due to the earth's rotation and the interchanging motions between the polar and equatorial regions are necessarily associated with the general motions of the atmosphere. They are *eastward* motions in the higher latitudes, which increase with increase of altitude, but *westward* motions near the equator, which decrease with an in-

crease of altitude, and at a certain elevation disappear and become eastward motions.

The question might be asked, what is the numerical value of this force which we call the deflective force due to the earth's rotation on its axis? It has a very significant value, which may be expressed by saying that if the air on the parallel of 45 degrees has a velocity of 54 miles per hour, it gives rise to a gradient of pressure, equivalent to one-tenth of an inch of mercury in the distance of one degree, of a great circle of the earth.

The deflective force varies as the velocity and the sine of the latitude, and therefore attains a maximum at the poles, and entirely vanishes at the equator.

It is not difficult to understand, therefore, that the general motions of the atmosphere are entirely independent of local disturbances, so far as their origin is concerned.

## SECONDARY MOTIONS.

Secondary motions of the atmosphere are those which arise as the result of a violent and prolonged disturbance of some of the general motions.

Secondary motions give rise to what are known as storms, while general motions give rise to slow and extensive movements between the equator and the poles.

Storms considered under this class of atmospheric motions comprise only those having the largest area of disturbance, such as the West India cyclones and land storms of general rain and snow.

On the synoptic chart these storms are indicated by iso-

metric lines of pressure drawn for differences of a tenth of an inch.

The centre of low pressure, viz: where the barometer and wind direction indicates the lowest pressure, is marked by the word "Low" on the chart, and is practically the centre of the storm, or atmospheric disturbance.

To explain the phenomena of secondary motions, we must consider as the "*primum mobile*" in the production of storms, that force which arises from a greater specific gravity of the atmosphere in some places than in others, because of the differences of temperature and of the dew-point.

When the air becomes heated, or charged with vapor at one place in excess of another, the air at the former becomes specifically lighter, and therefore the equilibrium at that place is destroyed.

There is an indraught, or flowing together from all sides towards the point of least pressure.

The heavier air on all sides displaces the lighter and causes it to ascend and flow outwards in a direction contrary to the movement at the surface.

The surface of the earth is neither uniformly land nor water, but on the contrary, a very irregular combination of both. If we look at the land areas, we find them furrowed here and there by the beds of great rivers whose watersheds embrace numberless smaller streams. Great mountain ranges, inland seas, and vast forests give rise to boundless irregularities on the surface.

The sun's rays, falling upon such a vast variety of surfaces gives rise to very unequal distribution of temperature, which

in turn, destroys any regular system of winds. Were it not for this want of uniformity on the surface of the earth, the trade winds, passage winds and calm belts would extend without any interruption entirely around the globe.

The passage winds are known as the southwest winds of the middle latitudes in the southern hemisphere.

The trade winds are the northeasterly winds of the northern hemisphere, having a polar limit beginning at about 10° N., to 28° N., in longitude 60° W., and 32° N., in longitude 15° E.

In the southern hemisphere, they are the southeasterly winds, extending from about 28° S., to a few degrees north to the equator.

The calm belt is located about 3° N. of the equator.

These well known features of atmospheric circulation result from interruption in the *general* movement of the air from the equator to the poles.

### DISTURBING INFLUENCES.

Continents, and especially high mountain ranges very materially deflect and disturb the normal conditions of atmospheric circulation.

The strong westward movement of the northeast trades strikes the Atlantic coast of North America and passes inland, with reduced velocity. Meeting the high mountains of the Rocky range, the currents are deflected, the northeast over the Mississippi valley and British America, and arriving at latitudes where the atmosphere has a general tendency to flow eastward, the effect of the general drift is realized, and

the movement continues over the Atlantic south of Greenland to the west coast of Europe, where the circulation again joins the trade-wind system.

We thus see the effect of large interruptions to the general movements of the atmosphere. Smaller changes must constantly take place where the tendency to extend abnormal variations exist to any great degree.

The interruptions of general notions may be caused by a greater rarefaction of the atmosphere at some places than at others. This may arise from a greater amount of heat, or a greater amount of aqueous vapor in the air. Superabundant heat or aqueous vapor will cause the air where it exists, to become more rare than the surrounding portions, and as a consequence an occasional current is formed, the encircling heavier air flowing in below to supply its place, while a counter current is produced above.

The air strata near the earth generally contain a certain quantity of aqueous vapor which is condensed in the ascensional current by the cold of expansion, forming clouds, and if the supply of vapor is sufficient, rain. The caloric which is given out by the process of condensation produces a still greater rarefaction than that due to the presence of direct heat and vapor, and probably adds very much to the disturbance of equilibrium and to the motive power of storms.

As long as the ascending atmosphere over the area of greatest rarefaction is supplied with aqueous vapor by the lateral currents flowing in from all sides, the disturbance of equilibrium must continue, and consequently the local disturbances of the atmosphere to which it gives rise.

The effect is the same whether it be an ordinary rain-storm or a cyclone, the disturbance continuing many days, during which period the general motions of the atmosphere have carried the disturbed area many hundreds of miles.

When the area of rarefaction is of such force and extent as to give rise to a constantly interchanging motion between the internal and external parts of the disturbance, the necessary machinery to set in motion, which if bountifully supplied with the requisite food (aqueous vapor), will preserve the energy of the disturbance intact until it has progressed to some point where the supply of vapor food is cut off.

By means of the interchanging motion between the internal and external parts of a disturbance, the former is compelled to gyrate around the centre from right to left in the Northern Hemisphere, and the external part the contrary, which gives rise to a revolving storm or cyclone.

The conditions are similar in the case of hemispherical motions, which in that part of the earth nearest the poles, occasions an eastward motion, and in that part nearest the equator, a westward motion.

We have here briefly presented the mechanism of storm generation, and by storm in this sense we mean the greatest atmospheric disturbances that pass over the earth.

As here used, a storm means an elliptical area of low pressure, the shortest axis sometimes having a length of from 200 to 500 miles, and the longer from 500 to 1,500.

## CYCLONES.

As we have before stated, this form of atmospheric disturbance is the outcome of secondary motions. Cyclones

have the largest area of all known storms, so large in fact is the region embraced by any single disturbance, that its internal and external motions are influenced by the rotation of the earth on its axis.

The West India cyclones form at the northern edge of the belt of calms about 10 degrees north of the equator, with a diameter of about 100 miles, which increases as the storm advances to 500 or even 1,000 miles. Their progressive movement is to the northwest bearing constantly north, but restrained from a direct movement towards the pole by the influence of the northeast trades.

The westerly movement of these storms is controlled by the general drift of the atmosphere in the trade wind belt (10 to 30 degrees N. latitude) which carries them along like the eddies in a river, When the northern edge of this belt is reached (30 degrees N. latitude) the cyclone changes direction, its path curving to the *northeast* under the influence of the general easterly trend of the atmosphere which prevails north of the trade-wind belt.

Tropical cyclones are mostly confined to a certain portion of the year, the months of greatest frequency being August, September and October.

All general storms that form and pass over the United States to the Atlantic Ocean, and thence to Europe, come under the description of the secondary motions of the atmosphere.

## LOCAL MOTIONS.

Local motions of the atmosphere are those which arise as

the result of a sudden and violent interruption of the secondary motions, taking place over a limited area.

Local motions give rise to what are known as tornadoes, hail-storms, water-spouts and whirlwinds.

Where atmospheric equilibrium is violently discomposed and the agitation covers but a very limited area, the centripetal force becomes much greater than in the case of cyclones. The gyrations are exceedingly rapid and very near the centre, in fact, the violence is greatest at the centre and diminishes rapidly to the external parts of the disturbance where the gyrations cease altogether.

This form of disturbance we call a tornado. In order that conditions may become favorable for tornadic development, the atmosphere must assume the unstable state. This state will be engendered whenever the rate of decrease of temperature is greater in the surrounding quiet air than it is in the mass of ascending air.

The adverse or counter movement of northerly and southerly winds induces the unstable state, because it makes the rate of decrease of temperature greater in the quiet air than in the column of ascending air, that is, the upper strata of the air will be made colder, and the lower strata warmer.

What are known as local storms under this class of motions of the atmosphere are not affected by the rotation of the earth upon its axis, because the area of disturbance is too small.

The progressive motion of tornadoes to the northeast arises from the fact that as they always form in the southeast quadrant of an area of low barometer, they must come within,

and under the influence of the general drift of the atmosphere on that side of the "Low," which according to the law of atmospheric circulation about the centre of an area of low pressure, is always to the northeast.

## TORNADO DYNAMICS.

The condition of tornado formation in regard to heat is simply that of unstable equilibrium for saturated air at the existing temperature, the other condition being that the air shall have a gyratory motion relative to some central point, arising from any cause whatever.

In the unstable state the lower strata of the atmosphere are liable to burst up through the upper layers at any point where there may chance to exist some slight predetermining cause, which is never wanting, arising from local conditions of temperature and moisture.

When an upward motion of the atmosphere is started at any point, the air thus engaged is kept warmer, and therefore rarer, than the region immediately surrounding it.

This continues as long as the ascending current is supplied with air nearly or quite saturated, or until, from an inversion of the air in the lower and upper strata, the state of unstable equilibrium is changed.

The violent whirling motion of the air which characterizes the tornado is dependent upon a pre-existing disturbed and gyrating state of the atmosphere.

The case is somewhat similar to that of water in a shallow basin running out through a hole in the centre. If the initial state of the water is that of perfect rest, it flows

THE TORNADO IN HENRY AND SALINE COUNTIES, MISSOURI, APRIL 18TH, 1882; 8 PEOPLE KILLED, 150 WOUNDED AND 61 BUILDINGS DESTROYED; LOSS, $180,000.

*directly* toward the centre, with a very slow velocity; but if there is the least initial disturbance of a gyratory character when the water first begins to flow, it soon runs into rapid gyrations around that center.

As we have shown, therefore, that there are two principal conditions upon which the occurrence of tornadoes depend, and in the absence of either of which they cannot take place. The one is the state of unstable equilibrium of the air, and the other a circulating motion with reference to any centre of disturbance.

It is not imperative that the central area shall be stationary, but simply that the motion of the air around it shall be such that when the latter is drawn in toward the centre it will take a gyration around it.

When these two principal conditions are present there is scarcely ever wanting the secondary condition, which, through the effect of some slight initial disturbance, gives rise to an upward burst of the air through the overlying strata.

The places and time most favorable to the development of unstable equilibrium and a gyratory motion of the atmosphere are those in which tornadoes are most likely to occur.

Of these two conditions, the unstable equilibrium is the most important, since it more rarely occurs than the other, which is scarcely ever so entirely absent as not to give some slight gyratory motion which becomes violent very near the centre.

The question naturally occurs, where are the places on the earth's surface and what is the time when conditions are most favorable for the development of tornadoes.

FIRST—as to places: These are found where, in the general motions of the atmosphere, as deflected by continents and mountain ranges, currents of air at the earth's surface which come from a warmer latitude, or at sea from a much warmer continent, are caused to flow under the colder upper strata where the normal motion is nearly eastward, and where consequently the temperature is the normal one, not affected by such motions as take place in the lower strata.

In other words, tornadoes are most likely to occur in regions where warm, moist air flows underneath a colder and dryer upper strata, coming from another direction.

Such regions are found, particularly in the Mississippi, Missouri and Ohio Valleys, and in Alabama, Georgia and the Carolinas.

The other condition of the atmosphere indispensable to the formation of tornadoes, viz: a relative gyratory motion with regard to any point, is found to an unusual extent in the regions above named, especially in the winter season, which fact accounts for the frequent occurrence of tornadoes in the Southern States during the winter and spring, and occasionally in the Mississippi and Ohio Valleys.

SECOND—as to time: The summer season is the most favorable for tornadoes, when the interior of the continent is warmed up and the air of the lower strata is drawn from lower latitudes far up into the northern portions of the country on the eastern side of the Rocky Mountains, and the isothermal curve is deflected very decidedly toward the north.

From this cause the temperature of the lower strata of

this region becomes much higher than that of the superdominant strata, and if this condition does not of itself induce the unstable state, it is readily accomplished by the addition of any small effect from some other cause, as from extremely warm weather, in which the earth's surface and the lower air strata become abnormally heated.

The great moisture of the air in the southerly winds is also favorable to the induction of the unstable state, since such a change is more readily brought about in air nearly or quite saturated.

The southerly currents curving eastward from the Rocky Mountain and Appalachian ranges give rise to a general air movement of considerable force toward the Atlantic Ocean, as the result of which, cold counter currents pass southward to Texas east of the Rocky Mountains and to Florida over the Appalachian range, somewhat after the manner of the Arctic current which flows southward to Florida between the Gulf Stream and the coast of the United States.

In the summer season this flow of cold air southward is confined to a comparatively narrow belt just east of the Rocky Mountains, for at that time the warm moist currents of the Gulf are drawn very far to the north and west.

At this season the northern part of Texas has the same mean temperature as Minnesota, the isotherms being nearly north and south in direction and the temperature gradient between the warm southerly winds on one side and the cold northerly currents on the other is similar to that of the cold wall between the Gulf Stream and Arctic current.

In the winter and spring the flow of cold air southward

from the higher latitudes extends to the Appalachian range where it overflows the warm moist southerly currents from the East Gulf and South Atlantic coast. It is this tendency of the air to flow in contrary directions, where the conditions are most favorable to produce the unstable state of the atmosphere, that pronounces the regions here indicated as the "battle ground of tornadoes."

## RECAPITULATION.

Let us briefly summarize the conditions of tornado development.

1st—The unstable stable of the atmosphere: For well known reasons this state occurs mostly in the cloud-region and hence tornadic gyrations usually commence there and are afterwards propagated downward to the earth's surface.

The tornado cloud invariably forms above and gradually decends to the earth, increasing rapidly in size and augmenting in power.

2nd—The opposing movement of warm, moist and cold dry air currents, the latter overflowing the former; or in other words, the surface winds from a lower latitude, or any warmer region, moving to higher latitudes while the normal temperature of the air above is not affected, or at least increased in the same way. This condition of things increases the temperature below and decreases it above, giving rise to the large vertical gradient of temperature, decreasing with increasing altitude, which is necessary to the unstable state.

3rd—The existence of a gyratory motion relative to some central point, arising from any cause whatever.

4th—Warm moist air, saturated or very nearly so, at the existing temperature.

## WHIRLWINDS.

The unstable state, may be produced in the lower unsaturated strata of the atmosphere. This occurs mostly on very dry and sandy soils with little heat conductivity, when the weather is very warm and the heat rays of the sun are unobstructed by clouds.

The heat thus accumulated in the surface strata of the soil and the lower strata of the atmosphere eventually induces the unstable state, at least up to a low altitude, even in clear and dry weather.

The whirlwind starts from the earth's surface, is propagated upward and moves forward in any direction, not leaving the earth, being solely confined to the region of surface currents.

The *whirlwind* disappears by descending to the earth, while the *tornado* is drawn upward to the cloud region.

Whirlwinds are not dangerous to either life or property, have a path a few feet in diameter and very short, and usually continue but a few minutes.

## WATERSPOUTS.

The unstable state of the atmosphere may also occur over the surface of lakes and other larger bodies of water, giving rise to what are termed waterspouts.

The surface of the water becomes heated and also the lower strata of the atmosphere, by heat rays passing directly down

and by those reflected back until there is an unusually rapid decrease of temperature with increase of altitude, or else a very nearly saturated atmosphere.

The gyration of the air is first observed near the water, accompanied by an agitation of the surface of the latter, and afterward the formation of the cloud above, resulting finally in the complete spout, unless the atmosphere is too dry.

Waterspouts cannot be considered altogether harmless, for there are instances where vessels have been wrecked by them, but they have not in any case exhibited the violence and continued force of the tornado.

## CONCLUSIONS.

We now understand the origin of the tornado, what leads to the development of the whirling cloud and how this destructive aerial monster differs from similar disturbances.

Solar heat is the controlling influence which disturbs the equilibrium of the atmosphere and gives rise to all the phenomena of storms. This fact must be kept clearly in mind and also the additional information that local conditions of heat, moisture and circulation may supervene to give peculiar effects to the general motions of the atmosphere.

With a right understanding of the nature and cause of tornadoes, better and more successful efforts are made in securing protection for life and property.

As has been previously stated we must start with the right premises in order to obtain the best results.

If any man looks upon the tornado as some mysterious convulsion of nature that is ordained to visit the earth by

a revengeful God, then all thought of material protection is at an end and he waits submissively in his tracks until the death-blow comes.

If one believes that the origin of tornadoes is purely electrical and that the force of the storm is maintained by the presence of electricity in some form or other, then his theory of protection must be constructed accordingly. The same may be said of the planetary theory.

According to the foundation so is the strength and security of the superstructure.

## THE ELECTRICAL THEORY.

There is no fact or record to show that an electrical discharge or any manifestation of atmospheric electricity ever entirely demolished a large stone or frame building; ever lifted a locomotive from the track; ever carried an iron bridge from its foundation and twisted the frame-work into a shapeless mass; ever rolled a boulder from its bed in the ground; ever embedded one piece of timber into another after having carried the former for several hundred yards in the air; ever carried bedding and clothing for miles in the air; ever elevated to considerable heights in the air columns of water from ponds, lakes, and rivers; ever lifted animals from the earth and carried them over buildings; ever drew the water from a well or cistern; ever twisted a tree from its stump; ever turned a building bottom side up or end for end, without otherwise injuring it. Many other effects of the peculiar manifestations of power in the tornado might be instanced to illustrate the impossibility of electrical intervention.

Electrical forces always act in straight lines, while the forces of the tornado are exerted in both straight and curved lines, or in any combination of them. Can any manifestation of electrical force twist the body of a hickory tree several times about its vertical axis?

## THE PLANETARY THEORY.

Any method of reasoning which assigns tornado development to planetary influences is, equally with the electrical theory of their origin, without foundation. We have but to realize that in the formation of the tornado, and other local storms of a similar character, the entire action of all the forces involved, even the energy of the sun's heat, is embraced in that portion of the atmosphere within from two to three miles of the earth's surface.

Any influence emanating from the movements, conjunctions, or other periodical mutations of the heavenly bodies, distant hundreds of thousands and millions of miles, can only reach an infinitesimal amount, and entirely inappreciable in its effect upon the atmosphere to produce local or general disturbances, especially near the earth.

It has been asserted that the conditions which give rise to the formation of the tornado cloud result from the effect upon the atmosphere of the mere revolution of the planets in their orbits; that circular movements in the atmosphere are propagated and continued by such influences. The effect is likened to that which would result from the whirling, in different directions in a large vessel of water, of several globes attached to the same spindle. Upon withdraw-

ing the globes, after a number of revolutions, the surface of the water will be found covered with a network of eddies.

The inherent fault of this simile is the fact that, while the illustration provides for the circular movement of the bodies within the medium which is set in motion to give the characteristic whirls or eddies, the subject of illustration, the planets, perform their revolutions, not in the atmosphere, the medium to be set in motion, but millions of miles away from it in another medium, concerning which little is known. The failure to properly apply the method of reasoning by analogy often leads the novice into making the most ridiculous assumptions. It would be more reasonable to assume that the revolutions of the planets give rise to the great disturbances of the atmosphere, embracing extended regions of country, which are known on the Weather Map as "Highs" and "Lows," but even here the same difficulties operate, although not so extravagantly as in the case of the tornado, with its narrow path of a hundred yards or more

## Table No. 1.

RELATIVE FREQUENCY OF TORNADOES BY MONTHS, FROM 1682 to 1887 INCLUSIVE, A I
OF 206 YEARS, BUT AN ACTUAL RECORD OF ONLY 88 YEARS.

| MONTHS. | No. of Storms. | No. of Storms, months & years not reported. | Total No. of Storms Observed. | No. of S for 1 |
|---|---|---|---|---|
| January | 35 | | | 1 |
| February | 115 | | | 2 |
| March | 168 | | | 1 |
| April | 345 | | | 2 |
| May | 363 | | | 2 |
| June | 312 | | | 2 |
| July | 262 | | | 2 |
| August | 161 | | | 1 |
| September | 120 | | | |
| October | 42 | | | |
| November | 58 | | | |
| December | 28 | 424 | 2435 | |
| TOTALS, | 2011 | 424 | 2435 | 17 |
| GRAND TOTAL | | | | |

## Table No. 2.

ESTIMATED LOSS OF PROPERTY DESTROYED BY TORNADOES.

| STATES. | Length of tornado record in years. | Valuation of property destroyed. | STATES. | Length of tornado record in years. | Valu pro dest |
|---|---|---|---|---|---|
| Alabama, | 1822 to 1887 | $38,175,000 | Michigan, | 1823 to 1887 | $26,4 |
| Arkansas, | 1840 " 1887 | 17,125,000 | Minnesota, | 1855 " 1887 | 50,7 |
| Colorado, | 1877 " 1887 | 500,000 | Mississippi, | 1823 " 1887 | 44,2 |
| Connecticut, | 1682 " 1887 | 7,500,000 | Missouri, | 1814 " 1887 | 94,3 |
| Dakota, | 1875 " 1887 | 7,500,000 | Nebraska, | 1871 " 1887 | 22,1 |
| Delaware, | 1885 " 1887 | 185,000 | New Hampshire, | 1807 " 1887 | |
| Florida, | 1875 " 1887 | 375,000 | New Jersey, | 1822 " 1887 | 16,( |
| Georgia, | 1795 " 1887 | 56,500,000 | New York, | 1787 " 1887 | 67,( |
| Illinois, | 1835 " 1887 | 46,125,000 | North Carolina, | 1826 " 1887 | 26,( |
| Indiana, | 1818 " 1887 | 35,800,000 | Ohio, | 1804 " 1887 | 87,7 |
| Indian Territory, | 1875 " 1887 | 1,250,000 | Pennsylvania, | 1811 " 1887 | 26,1 |
| Iowa, | 1837 " 1887 | 49,575,000 | South Carolina, | 1761 " 1887 | 46,8 |
| Kansas, | 1859 " 1887 | 64,000,000 | Tennessee, | 1808 " 1887 | 6,9 |
| Kentucky, | 1810 " 1887 | 4,000,000 | Texas, | 1853 " 1887 | 46,8 |
| Louisiana, | 1869 " 1887 | 5,500,000 | Vermont, | 1829 " 1887 | |
| Maine, | 1860 " 1887 | 375,000 | Virginia, | 1814 " 1887 | 3,( |
| Maryland, | 1833 " 1887 | 4,750,000 | West Virginia, | 1880 " 1887 | |
| Massachusetts, | 1809 " 1887 | 6,625,000 | Wisconsin, | 1843 " 1887 | 28,7 |
| TOTAL | | | | | $941,282 |

NOTE.—The estimated values above given are determined on the basis that the loss is, on the average, about 4 per cent. of the *actual* loss sustained, this deficiency from incomplete reports and the failure to give any valuation of loss in many cases.

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## Table No. 4.

A TORNADO RECORD OF 88 YEARS, CONSIDERED BY 11 YEAR PERIODS. PERIOD EMBRACED BY ENTIRE RECORD 206 YEARS.

| Year. | No. of Tornadoes. | Year. | No. of Tornadoes. | Year. | No. of Tornadoes. | Year. | No. of Tornadoes. | Year. | No. of Tornadoes. | Year. | No. of Tornadoes. | Year. | No. of Tornadoes. | Year. | No. of Tornadoes. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1682 | 1 | 1805 | 1 | 1820 | 1 | 1833 | 9 | 1844 | 5 | 1855 | 7 | 1866 | 8 | 1877 | 70 |
| 1728 | 1 | 1807 | 2 | 1821 | 3 | 1834 | 11 | 1845 | 4 | 1856 | 3 | 1867 | 10 | 1878 | 77 |
| 1729 | 1 | 1808 | 2 | 1822 | 3 | 1835 | 8 | 1846 | 2 | 1857 | 8 | 1868 | 4 | 1879 | 88 |
| 1761 | 1 | 1809 | 2 | 1823 | 6 | 1835 | 1 | 1847 | 2 | 1858 | 6 | 1869 | 6 | 1880 | 141 |
| 1787 | 2 | 1810 | 1 | 1824 | 3 | 1837 | 5 | 1848 | 3 | 1758 | 8 | 1870 | 11 | 1881 | 113 |
| 1788 | 1 | 1811 | 3 | 1826 | 2 | 1838 | 4 | 1849 | 2 | 1860 | 16 | 1871 | 9 | 1882 | 90 |
| 1791 | 1 | 1814 | 4 | 1827 | 2 | 1839 | 4 | 1850 | 3 | 1861 | 4 | 1872 | 12 | 1883 | 167 |
| 1794 | 1 | 1815 | 3 | 1829 | 4 | 1840 | 13 | 1851 | 6 | 1862 | 3 | 1873 | 14 | 1883 | 216 |
| 1795 | 1 | 1816 | 1 | 1830 | 9 | 1841 | 2 | 1852 | 3 | 1863 | 8 | 1874 | 21 | 1885 | 139 |
| 1797 | 1 | 1818 | 3 | 1831 | 3 | 1842 | 6 | 1853 | 5 | 1854 | 4 | 1875 | 81 | 1886 | 290 |
| 1804 | 3 | 1819 | 2 | 1832 | 4 | 1843 | 4 | 1854 | 15 | 1865 | 4 | 1876 | 64 | 1887 | 178 |
| Totals | 14 | | 24 | | 40 | | 67 | | 50 | | 71 | | 240 | | 1569 |

Total number of Storms, years not recorded..... 360
Grand Total..... 2,435

## Table No. 5.

A TORNADO RECORD OF 88 YEARS, CONSIDERED BY 22 YEAR PERIODS. PERIOD EMBRACED BY ENTIRE RECORD, 206 YEARS.

| Year. | No. of Tornadoes. | Year. | No. of Tornadoes. | Year. | No. of Tornadoes. | Year. | No. of Tornadoes. |
|---|---|---|---|---|---|---|---|
| 1682 | 1 | 1820 | 1 | 1844 | 5 | 1866 | 8 |
| 1728 | 1 | 1821 | 3 | 1845 | 4 | 1867 | 10 |
| 1729 | 1 | 1822 | 3 | 1846 | 2 | 1868 | 4 |
| 1761 | 1 | 1823 | 6 | 1847 | 2 | 1869 | 6 |
| 1787 | 2 | 1824 | 3 | 1848 | 3 | 1870 | 11 |
| 1788 | 1 | 1826 | 2 | 1849 | 2 | 1871 | 9 |
| 1791 | 1 | 1827 | 2 | 1850 | 3 | 1872 | 12 |
| 1794 | 1 | 1829 | 4 | 1851 | 6 | 1873 | 14 |
| 1795 | 1 | 1830 | 9 | 1852 | 3 | 1874 | 21 |
| 1797 | 1 | 1831 | 3 | 1853 | 5 | 1875 | 81 |
| 1804 | 3 | 1832 | 4 | 1854 | 15 | 1876 | 64 |
| 1805 | 1 | 1833 | 9 | 1855 | 7 | 1877 | 70 |
| 1807 | 2 | 1834 | 11 | 1856 | 3 | 1878 | 77 |
| 1808 | 2 | 1835 | 8 | 1857 | 8 | 1879 | 88 |
| 1809 | 2 | 1836 | 1 | 1858 | 6 | 1880 | 141 |
| 1810 | 1 | 1837 | 5 | 1859 | 8 | 1881 | 113 |
| 1811 | 3 | 1838 | 4 | 1860 | 16 | 1882 | 90 |
| 1814 | 4 | 1839 | 4 | 1861 | 4 | 1883 | 167 |
| 1815 | 3 | 1840 | 13 | 1862 | 3 | 1884 | 216 |
| 1816 | 1 | 1841 | 2 | 1863 | 8 | 1885 | 139 |
| 1818 | 3 | 1842 | 6 | 1864 | 4 | 1886 | 290 |
| 1819 | 2 | 1843 | 4 | 1865 | 4 | 1887 | 178 |
| TOTALS, | 38 | | 107 | | 121 | | 1,809 |

Total number of Storms, years not recorded..... 360
Grand Total..... 2,435

## COMPENDIUM.

As the limits of this book will not permit a consideration of details, I must summarize the results of many years of study and observation, and the collection of a vast amount of data, into the following paragraphs.

The word "Low," as has been stated elsewhere, marks upon the Weather Map the center of lowest pressure, as indicated by the barometer and direction of the wind. This is practically the center of the general storm or atmospheric disturbance.

1. The conditions for the development of tornadoes are most favorable in the *southeast quadrant* of a "Low." In fact they are not to be looked for in any other portion of the general disturbance.

2. Tornadoes very generally accompany a "Low," for the reason that the condition of unstable equilibrium necessary in the formation of a tornado is also required in the "Low," at least in the upper cloud-region.

3. The unstable state in a "Low" very rarely extends down to the earth's surface so that tornadoes are not necessarily visible in every general storm.

4. There are frequently secondary whirls, incipient tornadoes, in the cloud-region of a "Low," the effects of which do not reach down to the earth's surface, and the only visible effect above is the formation of a local cloud a little denser and darker than the cloud area generally.

5. A hail-storm is an incipient tornado in the cloud-region of a "Low."

6. Tornadoes always occur in the *southeast quadrant* of a

## Table No. 6.

COMPARATIVE VALUES OF PROPERTY LOSS BY TORNADOES AND BY FIRE, DURING A PERIOD OF NINE (9) YEARS, 1876 TO 1884.

| STATES. | No. of Tornadoes reported in 9 years, 1876 to 1884. | Property loss by Tornadoes, 9 years, 1876 to 1884. | Property loss by Fire, 9 years, 1876 to 1884. | Entire period Tornado record in yrs. to include 1887. |
|---|---|---|---|---|
| Alabama, | 46 | $7,794,828 | $6,168,672 | 66 |
| Arkansas, | 31 | 2,567,710 | 6,418,733 | 48 |
| Colorado, | 3 | 454,500 | 5,331,670 | 11 |
| Connecticut, | 3 | 364,080 | 14,403,754 | 206 |
| Dakota, | 24 | 3,777,776 | 4,132,320 | 13 |
| Florida, | 6 | 259,614 | 4,370,499 | 13 |
| Georgia, | 76 | 12,153,288 | 14,082,580 | 93 |
| Illinois, | 67 | 11,419,810 | 38,059,607 | 53 |
| Indiana, | 41 | 8,674,287 | 22,980,775 | 70 |
| Indian Territory, | 3 | 865,395 | 141,600 | 13 |
| Iowa, | 69 | 10,983,820 | 14,820,783 | 51 |
| Kansas, | 106 | 16,413,790 | 6,108,408 | 29 |
| Kentucky, | 15 | 1,115,380 | 13,066,487 | 78 |
| Louisiana, | 15 | 1,657,890 | 11,691,847 | 19 |
| Maine, | 3 | 120,537 | 13,314,333 | 28 |
| Maryland, | 6 | 922,724 | 9,023,240 | 55 |
| Massachusetts, | 9 | 1,185,121 | 49,104,488 | 79 |
| Michigan, | 33 | 5,887,535 | 30,582,680 | 65 |
| Minnesota, | 41 | 10,477,240 | 18,752,430 | 33 |
| Mississippi, | 32 | 7,130,377 | 5,479,110 | 65 |
| Missouri, | 121 | 20,674,659 | 27,129,452 | 74 |
| Nebraska, | 32 | 4,111,761 | 3,342,878 | 17 |
| New Hampshire, | 3 | 25,362 | 7,866,473 | 71 |
| New Jersey, | 2 | 2,181,816 | 21,442,589 | 66 |
| New York, | 28 | 8,630,000 | 124,766,790 | 100 |
| North Carolina, | 33 | 6,961,686 | 6,485,569 | 62 |
| Ohio, | 30 | 18,257,585 | 41,495,601 | 84 |
| Pennsylvania, | 18 | 4,053,565 | 69,868,711 | 77 |
| South Carolina, | 38 | 8,195,650 | 7,746,534 | 127 |
| Tennessee, | 15 | 1,435,903 | 10,364,785 | 80 |
| Texas, | 32 | 8,677,852 | 21,808,785 | 35 |
| Vermont, | 2 | 95,337 | 7,001,950 | 59 |
| Virginia, | 8 | 776,014 | 8,113,425 | 74 |
| West Virginia, | 1 | 337,500 | 3,160,365 | 8 |
| Wisconsin, | 34 | 6,749,992 | 21,375,243 | 45 |
| TOTALS, | 1,025 | $195,390,384 | $666,843,801 | 5,659 |

NOTE.—The fire statistics are taken from the "Chronicle Fire Tables of 1885." The tornado statistics, as to estimated loss of property, are probably not as reliable as those representing the loss by fire, because of the imperfection of reports and the want of adequate means to ascertain the actual loss attendant upon any storm. While in some States the *estimated* loss appears rather excessive, yet in the majority of cases it is evidently deficient, which fact would render the total *estimated* loss for the country considerably below the *actual* loss sustained. In the column giving the number of tornadoes *reported* from each State during a period of nine years, the data must not be considered as exact, for many storms have evidently occurred, concerning which no reports were rendered. The period given in the table embraces the time during which the most destructive storms ever known to this country occurred. Excepting the year 1886, the proportion of storms was considerably greater during this period than before or since.

The property loss from tornadoes must necessarily be greater as the country grows older, and the destruction is not subject to control as in the case of fire loss.

THE TORNADO OF WALTERBOROUGH, SOUTH CAROLINA, APRIL 16TH, 1879; 16 PERSONS KILLED, 75 WOUNDED AND 50 BUILDINGS DESTROYED; LOSS, $200,000.

"Low" and at distances, generally, of 200 to 500 miles from the center of it.

7. Tornadoes are not likely to occur in the southwest and northwest quadrants of a "Low" because the currents and counter-currents there are nearly east and west, and hence the effect is neutral, neither tending to produce or destroy the unstable state.

8. As a "Low" progresses eastward the region of country lying to the south and east of the center of the general storm, at any time, is the region where tornadoes are to be looked for.

People residing in the other quadrants (SW. NW. NE) of the "Low" need not fear the occurrence of tornadoes.

Complete benefit cannot be obtained from this information without the use of the Signal Service Weather Map which shows, twice a day (8 a. m. and 8 p. m.) the location, direction of movement and intensity of the "Low."

9. Owing to the fact that the wind in a storm draws towards its centre, the following rules for determining that location, when the direction of the wind is given, may be found useful:

| *Wind.* *Northern Hemisphere.* | *Bearing of Centre.* |
|---|---|
| North . . . . . | E. S. E., or more Southward |
| N. E. . . . . | S. S. E., or more Southward |
| East . . . . . | S. S. W., or more Westward |
| S. E. . . . . | W. S. W., or more Westward |
| South . . . . . | W. N. W., or more Northward |
| S. W. . . . . | N. N. W., or more Northward |
| West . . . . . | N. N. E., or more Eastward |
| N. W. . . . . | E. N. E., or more Eastward |

The conditions are reversed in the Southern Hemisphere.

10. The study of the relation of tornado regions to the form of barometric depressions seems to show that tornadoes are more frequent when the major axis of the barometric trough trends north and south, or northeast and southwest than when it trends east and west.

11. The general direction of movement of the tornado is invariably from a point in the southwest quadrant to a point in the northeast quadrant.

12. The tornado cloud assumes the form of a funnel, the small end drawing near, or resting upon the earth.

13. The cloud and the air beneath it revolve about a central vertical axis with inconceivable rapidity, and always in a direction contrary to the movement of the hands of a clock.

14. The destructive violence of a tornado is sometimes confined to a path a few yards in width, or it may widen to the extreme limit of eighty rods.

15. The tornado, with hardly an exception, occurs in the afternoon, just after the hottest part of the day.

16. The hours of greatest frequency are 3:30 to 4 p. m., and 4:30 to 5 p. m.

17. The destructive power of the wind increases rapidly from the circumference of the storm to its center.

18. Observations with a single barometer will not indicate the approach of a tornado, however near the position of the instrument to the path of the storm, but such observations are of value in this connection, only when a number of them are displayed upon the daily Weather Map.

19. The Tornado season includes the months of March, April, May, June, July, August and September. There are,

however, cases in a long series of years where tornadoes have been reported every month of the year.

20. The months of greatest frequency, as determined from a record of 206 years, are April, May, June and July.

21. The month of greatest frequency is May, April coming next on the list.

22. The State in which the greatest number of tornadoes have occurred is Missouri, followed next in order by Kansas and Georgia.

The 425 tornadoes and "windfalls" recorded in Wisconsin far exceeds the number from any other State, but proper weight can not be given this fact owing to the want of similar investigation of the subject of "windfalls" in other States.

23. The violence of tornadoes expressed relatively by States, places Missouri first, succeeded by Iowa and Alabama. By violence in this sense is meant the most completely developed storms with perfect conditions longest sustained.

Considering the entire record of eighty-eight years nearly 4000 persons have been reported killed and 6000 injured. This record is very imperfect owing to the large number of cases in which the killed and wounded were not definitely reported.

24. The States in which tornadoes have proved the most destructive to life are in relative order as follows:

Missouri, Mississippi, Iowa, Illinois, Minnesota, Wisconsin and Ohio.

25. Considering the reported valuation of property destroy-

ed by tornadoes, the following States have experienced the most destructive storms, and in the order named :

Ohio, $8,309,500 in 84 years ; Minnesota, $5,790,000 in 33 years ; Missouri $2,853,000 in 47 years ; Mississippi, $1,-771,000 in 65 years ; Iowa, $1,583,000 in 45 years ; Wisconconsin, $1,145,000 in 44 years. These values are largely underestimated owing to the imperfection of reports. It is calculated that, on the average, these values represent about four per cent of the actual loss sustained.

26. Accepting the data in the above table as failing to represent the actual value of the property destroyed by about 96 per cent, and considering the length of record involved, and the increase in the value of property during the past 25 years, the approximate loss to property in the United States from the ravages of tornadoes is estimated at $781,047,500, which is, without doubt, an underestimate, even at one billion dollars.

27. Comparing the relative frequency of tornadoes by States, according to the area of each in square miles, we find that the following States stand highest and in the order named :

Kansas, Iowa, Illinois, Nebraska, Indiana, and Massachusetts.

28. Comparing the relative frequency of tornadoes by States, according to length of the record of observations in each, the following States head the list and in the order named : Kansas, Dakota, Missouri, Nebraska, Illinois, Minnesota and Texas. This comparison necessarily gives a

high percentage to the State having a short record but a large number of storms.

29. A comparison of the yearly values in the preceding tables might lead one to the conclusion that tornadoes were on the increase. Such a deduction would certainly be erroneous, and for the following reasons:

*First.* From a careful investigation of the origin of tornadoes and their geographical distribution, there is every reason to believe that these storms were as frequent and violent two hundred years ago as now. Moreover, there appears to be no cause for any unusual change in the annual frequency of tornadoes for a like period to come.

*Second.* It must be considered that during the past ten years the Signal Service has had greater facilities for collecting reports, and the rapid growth of the country, with a greater zeal of the Press, has brought to light the occurrence of many storms which otherwise would not have been reported.

*Third.* The preceding tables are not sufficiently complete, especially prior to 1875, (without which period it would not be safe to make deductions) to permit of reliable conclusions as to periods of maximum and minimum occurrence.

It is not unlikely that such variations exist and that they depend upon the relations of heat and moisture to the general condition of the atmosphere. The more frequently the unstable state of the atmosphere is produced, together with a relative gyratory motion, the more favorable are the conditions for the occurrence of tornadoes, and *vice versa.*

*Fourth.* In the region between the 95th and 107th meri-

dians, tornadoes still occur without causing much damage, because of their passage over thinly settled portions of country. Owing to this fact little attention is given to these storms, but this indifference will soon disappear as the country rapidly settles up and every appearance of the cloud monster is marked by death and destruction.

*Fifth.* The years (118) that are missing from the preceding tables, in the period of 206 years, from 1682 to 1887, inclusive, are not to be considered as years in which no tornadoes occurred, but as years in which records are wanting owing to the failure of observations.

30. Considering the past ten years (1878 to 1887, inclusive) as furnishing reliable and exhaustive records of tornadoes, and that the period prior to 1878, (196 years, 1862 to 1877, inclusive) is deficient owing to want of facilities in collecting reports, we may give an interpolated value for each of these latter years, as determined from the complete ten year record.

This value is found to be 146, which means that, on the average, 146 tornadoes will occur yearly in the United States.

Applying this value to the above tables, we have a grand total of storms from 1682 to 1887, inclusive, (206 years) of 30,076 tornadoes, instead of 2,435, as shown above. This would indicate a failure to report the occurrence of about 27,641 tornadoes which have probably passed over portions of this country since 1682. In that year a very destructive tornado, with distinct funnel-shaped cloud, visited New Haven, Connecticut, at 2:30 p. m., on the 10th of June.

It is the very long interval of 118 years, during which re-

cords are entirely missing, that makes the discrepancy so great in the grand totals.

31. The season of tornado formation with respect to the region of country where such storms are likely to occur, may be considered generally, and the following geographical divisions are made of the country east of the Rocky Mountains, which will afford a fairly reliable means of knowing the region of country in which tornadoes occur at certain seasons :

*First Period.* December to March, inclusive, comprising the region embraced by the following States: North Carolina, South Carolina, Georgia, Florida, Alabama and Kentucky.

*Second Period.* April to June, inclusive, region: Mississippi, Tennessee, Texas, Louisiana, Arkansas, Missouri, Michigan, Kansas, Illinois, Indiana, Ohio, Colorado, Iowa and Nebraska.

*Third Period.* June to August, inclusive, region: Dakota, Minnesota, Wisconsin, Western Pennsylvania, Western New York and West Virginia.

*Fourth Period.* August to November, inclusive, region: Virginia, Maryland, Delaware, New Jersey, Eastern Pennsylvania, Eastern New York and the New England States.

32. No well authenticated case of a tornado has been reported from the region of country lying west of the 105th meridian, and it may be generally stated that that these storms do not occur in the United States west of the 100th meridian. The cause for this is found in the lack of favorable conditions, on account of the dryness and the lower

temperature of the air, and the want of uniformity in the direction and force of surface currents.

Violent straight winds, attended with considerable destruction to property, have been reported several times in the past fifteen years from Southern and Central California, Arizona, New Mexico, Wyoming and Montana.

33. Much has been said and published concerning the influence of forests upon the occurrence and destructiveness of tornadoes, and many people believe that where timber grows in great abundance tornadoes cannot occur.

By comparing the number of tornadoes in each State with the acreage of forests as estimated in the last census report, it is found that the latter appear to have no perceptible influence in preventing the occurrence of tornadoes or in assuaging their violence.

Alabama has 10,430,727 acres of forests as against 22,554,873 acres of cleared land, but the records show that 107 tornadoes have occurred in that State.

Georgia has 15,269,225 acres of forests and 22,477,975 acres of cleared land, but 137 tornadoes have occurred in that State.

Missouri has 10,137,490 acres of forests and 33,855,610 acres of cleared land, but 160 tornadoes have occurred in that State, which is the largest number for any State in the country, except Wisconsin which has so many "wind-falls."

Kansas has 991,187 acres of forests and 51,296,813 acres of cleared land, with 165 tornadoes, but it is quite evident that the large preponderance of cleared land does not give rise to the large number of tornadoes. If this was a fact,

then Kansas should have many more tornadoes than Missouri, and they ought to prove more destructive, which happily is not the case.

Illinois has had 132 tornadoes and her forests embrace nearly five million acres. It may be generally stated that the great tornado States of the country have the largest acreage of forests.

34. In this connection it should not be forgotten that the conditions which give rise to the development of tornadoes exist in the cloud-regions of the atmosphere, and not at the surface of the earth.

Forests would prevent the occurrence of whirlwinds because these phenomena depend upon the unstable state of the atmosphere at the earth's surface, where the conditions are favorable for the sun's heat to accumulate in the surface strata of the soil, and thus superheat the air resting upon it. Forests or rank vegetation will prevent this action of the sun's rays.

Whenever a tornado cloud encounters a forest the destruction is complete and terrible.

The forces of the tornado cloud are quickly brought into operation and maintained continuously while the phenomenon exists. They are not affected by having to meet in rapid succession, totally different objects, different in size, strength, shape, materials, composition structure, relative position, etc.

35. The width of the path of destruction varies from 10 to 10,560 feet, the average being 1,369 feet.

36. The length of the tornado's track varies from 300 yards to about 200 miles, the average being 24,79 miles.

37. The velocity of progression of the tornado cloud varies from 7 to 100 miles per hour, the average being 44,113 miles.

These extremes may and often do occur in different portions of the track of a single tornado.

38. The shortest time occupied by the tornado cloud in passing a given point varies from "an instant" to about 20 minutes, the average being about 74 seconds.

39. The month of greatest frequency, that is the month embracing the largest number of days in which tornadoes occurred, is May.

40. The prevailing direction of the progressive movement of the tornado cloud is northeast.

41. The vortex wind velocities of the tornado cloud vary from 100 to 500 miles per hour, as deduced from actual measurements. Velocities of 800 to 1,000 miles per hour are extremes that have been reported, but may not be altogether reliable.

Theoretical velocities of 2,000 miles and over per hour, based upon certain assumed atmospheric conditions, have been deduced.

Such velocities are mathematically possible, but not meteorologically probable.

42. The concomitants of the tornado are: An oppressive condition of the air. The gradual setting in and prolonged opposition of northerly and southerly currents over a considerable area. A high temperature and the presence of considerable moisture. A gradual but continued fall of the thermometer, with a prevalence of the northerly currents, and a rise with the predominance of the southerly. A rapid decrease

of temperature with increase of altitude. A decided gradient of temperature across the line of progressive movement. Hugh masses of dark and portentous clouds in the northwest and southwest, possessing a remarkable intensity of color, usually a deep green. A remarkable rolling and tumbling of the clouds, scuds darting from all points of the compass toward a common center. Hail and rain accompanying the tornado, the former either in unusual size, form or quantity, and the latter either remarkable in quantity or size of drops. The presence of ozone in the wake of the tornado. A remarkable roaring noise, like the passage of many railroad trains through a tunnel.

The cloud generated by the vortex assumes the form of a funnel, with the smallest end toward the earth. The remarkable contraction of the storm's path. Upon reaching the earth's surface, the vortex has four motions, viz. First —The whirling or gyratory motion, always from right to left; Second—The progressive motion, generally from some point in the southwest quadrant to some point in the northeast quadrant; Third—The ricochet motion; Fourth—The oscilatory motion.

43. The characteristic effects of a tornado are : Objects are drawn toward the vortex from every point of the compass. Objects passing into the vortex are thrown upward and outward by the vortical action of the engaged air. Structures are literally torn to pieces by the vortical action of the air, evidence of which is afforded both by the fineness of the debris and also its disposition in the storm's path. The debris is thrown inward from each side of the storm's path. Light

objects are carried to great heights and also to great distances. Objects are carried inward and upward by the centripetral and outward by the centrifugal force of the vortex. Weight or size are conditions which generally present immaterial values to the power of the tornado. Persons are stripped of clothing. Fowls and birds are denuded of feathers and killed. Trees are whipped to bare poles. Heavy objects are carried for miles in the the air. Long and heavy timbers are driven to considerable depths in the solid earth. The vortex is completely filled with flying debris. Timbers are driven through the sides of buildings. Sand and gravel are driven into wood. Human beings and animals are run through with splinters and timbers. Straws, bits of glass and pieces of metal are driven into wood. The strongest trees are uprooted or twisted off near the roots. Men and animals are terribly maugled by contact with flying debris and by being rolled over the ground for considerable distances. In the path of the storm all vegetation is destroyed. Railroad trains are thrown from the track. Iron bridges are completely dismantled and carried from their foundations. Heavy bowlders, weighing tons, are rolled along the earth. The largest railroad engines are lifted from the tracks on which they rest. All objects, whether metal or non-metallic, magnetic or non-magnetic, simple or compound, animate or inanimate, are acted upon in a similar manner.

## WHAT ARE THE LOCAL SIGNS OF CONDITIONS FAVORABLE TO THE FORMATION OF TORNADOES?

1. The prevalence of southerly winds with a gradual but continued increase of heat and moisture.

2. A sultry and extremely oppressive condition of the atmosphere, which is sometimes characterized as "sticky," or so quiet as to call forth the remark that "there is not a breath of air stirring."

3. The form, color, motion, character of development and place of formation of the clouds. The sudden appearance of ominous clouds, first in the southwest and then almost immediately in the northwest and north, is sufficient to attract the attention of the most casual observer.

In nearly all instances these premonitory clouds are unlike the ordinary formation which signifies rain and perhaps a thunderstorm. If the clouds are light they resemble smoke rising from a burning building; if dark they present a deep greenish hue which appears to increase in intensity as the storm advances. Sometimes these dark clouds appear as densely black masses of smoke rolling upward from the chimney of an engine.

The motion of the clouds are peculiar in that they appear to be rushing from every quarter toward a common center, marking the incipient stages of a gyratory motion in the cloud-region.

The next step in the process of development is the appearance of a small, darting tongue of cloud which suddenly proceeds downward from the center of commotion and ulti-

mately reaches the earth as the full fledged funnel-shaped tornado cloud.

This brings us to consider—

### WHAT ARE THE SIGNS OF ITS APPROACH.

1. The tornado cloud is of course not visible from all directions while sweeping over the earth. The limit of vision is necessarily greater in some cases than in others, depending upon the topography of the intervening country.

2. Where the funnel cloud cannot be seen its existence can readily be distinguished by a peculiar roaring noise, which is likened to the rumbling of distant thunder or the approach of a heavy train of cars. The noise is said to resemble the "sighing of the wind through a forest."

3. As the storm approaches nearer, the sound increases in intensity until the final crash of the elements, which comes with the suddenness of an explosion. The noise is sufficiently peculiar and distinct to create alarm and as a means of *warning* must not be ignored.

4. A few minutes before the assault there is a death-like stillness in the air. The observer's eye catches the absence of any movement in the leaves upon trees, which a moment before danced in a gentle wind. This ominous silence portends grave results and requires that no time be lost in seeking the most perfect means of safety.

### THE TORNADO CLOUD.

Its form in individual cases is somewhat variable, but it always tapers from the top downward, the smaller end being nearest the earth.

It is described by eye-witnesses as resembling an "elephants trunk," balloon-shaped, basket-shaped, egg-shaped, &c.

While passing along its path the cloud is characterized by four distinct motions, which may be designated as:

1. The *Progressive* motion, generally from some point in the southwest quadrant to some point in the northeast quadrant.

2. The *whirling or gyratory* motion, always from right to left, or contrary to the movement of the hands of a watch with the face upward.

3. The *curvi-linear* motion. Frequently the cloud rises from the earth, breaking the continuity of its path for a distance of several rods to as many miles. Then it returns suddenly to the earth with renewed energy continuing its violence as before.

4. The *oscilatory* motion, a swaying from side to side of the central line of cloud movement. This motion is sometimes quite sudden, but generally it is a moderately slow movement and easily identified.

The regularity of it depends upon the frequency and severity of the indraught of air from the south side of the storm's path, into the vortex of the cloud.

It is important here to state that the *south* or *right hand side* of the tornado is the most *dangerous* part of the storm, as it is also the case with the cyclone. On this side the inflow of air toward the vortex coincides, both with the progressive motion of the tornado and the general easterly

movement of the "Low," thereby increasing the velocity of the southerly currents.

On the *north* or *left hand side* of the tornado the incurving winds oppose the direction of the currents advancing to the vortex and therefore the force of the wind is very much less on this side. It is therefore the *safest* side of the storm.

The tornado cloud is swept along by the general currents prevailing in the southeast quadrant of the "Low" and whatever may suddenly affect these movements will also extend its influence to the tornado cloud, and thus increase or diminish its gyrations, sometimes to the extent of withdrawing the cloud entirely from the earth.

The tornado continues in the full manifestation of its power until the force arising from the gyrations is no longer able to keep the pressure and temperature in the vortex low enough to cause condensation, and therefore the lower part of the cloud vanishes first, the decrease of power continuing until nothing appears of the funnel, and a dark, irregular mass of cloud marks the spot from which the spout had previously depended.

## "WINDFALLS."

"Windfalls" are the tracks of tornadoes through forests as shown by the prostrated and confused masses of timber. In many casees there remains but the skeleton of these ruins and their location is known only to Indians, trappers, hunters and surveyors.

There is not a State east of the Rocky Mountains that has escaped these serrated tracks through its forests and the

record of their occurrence will, in many cases, be found upon the plats of the early State surveys.

"Windfalls" both of recent and very early date, are still to be found in the heavy forests east of the Mississippi.

The late Prof. I. A. Lapham, of Milwaukee, Wisconsin, attached to the Signal Service in 1870—1872, made, in the latter year, a very exhaustive and interesting report on the "windfalls" of Wisconsin. As the result of a careful examination of the plats of public surveys made within the State, he discovered and marked upon a chart the location and approximate length of path of 360 "windfalls," or tornadoes.

According to the records of the Signal Service, the total number of tornadoes in Wisconsin for the period 1844 to 1887 (14 years) is 65. Add to this record the number of "windfalls" reported by Lapham and we have the remarkable total of 425 tornadoes.

The length of these "windfalls" varied in the extreme from 1 to 55 miles, the majority extending a distance of from 2 to 5 miles, but in all instances showing great violence.

A still more remarkable feature of these "windfalls" is the statement made by Prof. Lapham, that they are supposed to have all occurred within a period of about ten years, or at the rate of 36 storms per year.

If this be the fact, and the records seem to warrant the statement, then Wisconsin is certainly one of the tornado States and the record from 1844 to 1887 should be increased from 425 to 1,584 tornadoes.

If the average yearly number of tornadoes for Wisconsin is 36, then the record for 1887 is about 17 per cent. below the normal.

The Wisconsin "windfall" data makes apparent the imperfect records of the Signal Service as to the number of tornadoes in each State and the importance of completing these records, as far as possible, by a careful examination of the plats of public surveys in each State. It may be that some of the "windfalls" reported by Prof. Lapham were caused by straight winds and not by the "twister," the western *nom de plume* for tornado, but it is hardly likely, as the track of a "windfall" shows a perfect swathe cut through the forest, and such power, especially in the interior of the country, is not manifested by surface winds blowing from one direction.

The reader is now familiar with the origin, mode of development and characteristics of the tornado, so that he is prepared to consider the important and practical question of how to protect life and property.

Every person who thoroughly understands and appreciates what precedes will make the best use of what follows:

## PROTECTION TO LIFE.

The successful accomplisnment of this object depends upon the position and surroundings of the observer on the approach of the tornado, the character of motion possessed by the tornado cloud at the time, the width of the path of the storm and the velocity with which it is moving.

The following precautions which have been determined

upon as the result of careful investigation, observation and experience are arranged in short paragraphs for easy reference and ready memorizing.

If these rules and suggestions are strictly complied with, they can be depended upon as furnishing practical means for securing ample protection to life and limb.

1. The *south* side is the *dangerous* portion of a tornado; the *north* side is the safe portion.

2. In the open country never undertake to escape from a tornado cloud, without first making sure of the points of the compass, and that the direction which you propose to take is a line at *right angles* to the path of the advancing cloud.

3. If the cloud is moving to the northeast, then the line of escape is to the *northwest*; if to the east, then to the *north*. Stand facing the advancing cloud in the direct line of its approach and the *safe side is always to the right*.

4. To make escape certain, the tornado cloud should be about three-fourths of a mile distant. This gives the observer a momentary chance to ascertain the character of motion it possesses, the velocity of progression, the width of the path and the points of the compass.

These estimates must of necessity be approximate but can be made sufficiently accurate to be depended upon. At a greater distance than three-fourths of a mile it would be difficult, in most cases, for the observer to obtain this information with any degree of satisfaction, unless the atmosphere was clear and the cloud advancing over the open prairie.

It is presumed in this case, of course, that the observer has been watching the approach of the tornado for sometime. There is always *sufficient* warning of the *approach* of these storms and plenty of time to prepare for them if the *warnings* are *heeded.*

But there are always people who will persist in postponing action until it is too late to receive any benefit from it.

5. Make every effort to retain command of all of your senses on the approach of a tornado, because your safety largely depends upon acting judiciously, as well as correctly and quickly.

6. When trying to escape from a tornado never run to the *northeast, east* or *southeast.*

7. If the tornado cloud is possessed of the *oscilatory* motion, swaying from side to side of the central line of cloud movement, the greatest care must be exercised in trying to make one's escape.

However much the cloud may depart from its general direction of progression, it will eventually come back to that *direction* further on in its course, so that when the entire track is projected upon a chart it will be seen that the general direction has been preserved, no matter what the departure may have been at any time.

If the cloud is zigzaging, wait until it has recrossed the track to the *south* and then move quickly to the *north* or *northwest.*

8. Never take refuge in a forest, a clump of trees or near any object than may be overturned by the wind. Your chance of escape from any injury is very much greater in

the open field, where you can watch the cloud and take the proper action at the right time.

9. Suppose the tornado cloud to be distant from the observer 160 rods and its progressive velocity (the average) 44 miles per hour, it would then follow that one mile is passed in 82 seconds and 160 rods in 41 seconds. Assuming the average width of the tornado's track to be 80 rods and the position of the observer at the centre of that path, watching the advancing cloud, it will be seen that he has about 41 seconds in which to run a distance of about as many rods.

It is apparent from this calculation, which is based upon average results and rather underestimated, that the observer must act quickly and intelligently.

10. A frame building is safer than one built of brick or stone. The former is more elastic and holds together longer. The latter goes down in the first crash and the debris is whirled into a heap in the center of the foundation. This is especially the case where a brick or stone building stands alone. In a block of such buildings one structure supports another and there is not quite so much danger of *entire* destruction.

In any event, however, the brick or stone building is the most dangerous, because it so readily crumbles and separates into falling masses, that the inmates are never safe from injury.

11. In a *frame* structure the safest *place* is in the *cellar*, but in a *brick* or *stone* structure it is the most *dangerous*. In the former case if the building is destroyed it is invariably

carried away from the foundation. In the latter case the cellar is filled with debris.

12. The safest building to construct is one made entirely of wood, with a "barn frame," and not to exceed one story and a half in height. Where several buildings are connected together in a row, the height may be increased one or more stories with safety.

13. No structure that rises above the surface of the earth, however made, can resist the violence of a tornado, and therefore *no building is safe as property or as a resort to protect life.*

14. Under no circumstances, whether in a building or a cellar ever take a position in a *northeast room, in a northeast corner, in an east room or against an east wall.* Remember that the storm always approaches from the *west* and passes to the *east,* thus carrying all debris away from the *west wall.*

15. If the observer's position, regarding the tornado cloud, is such that he cannot escape from its fury by running in the proper direction, then he should throw himself *prone* (face downward) upon the ground, head to the east and arms placed over the head to protect it. Never remain *standing* and attempt to weather the storm; it would probably cost you your life.

If one chances to be near a large stone or stump, or some heavy object low down and firmly imbedded in the ground, take a position directly to the east of it, lying prone upon the earth, head toward the object, protecting the former with folded arms. This advice is to be followed *only* in case of an *emergency,* when other and better opportunities have been forfeited.

16. It is better, if possible, never to take refuge near any object located within the centre of the storm's path, especially not a tree or any object that rises some distance above the surface of the ground.

17. If *compelled* to remain in a *building* not provided with a cellar, take a position on the first (ground) floor. Go to the *west* room, stand near the centre of it and await the storm. If it appears that the building will be entirely *destroyed* then it is possible that the debris will be carried over and beyond you. If it is evident that only a *portion* of the house will be destroyed then seek safety in the *east* room, standing near the centre of it, for it is this *portion* of the house that will *remain*, in case of partial destruction.

*Under any circumstances* it is extremely *perilous* to remain in a *house* if it stands in the path of the tornado. Life and limb are in constant danger and there is nothing like safety to be secured.

## THE CELLAR-CAVE.

19. The *tornado cave* offers *absolute* security to life and limb and *nothing* can *replace* it for that purpose. This retreat may be constructed as a *cellar-cave* or as a "*dug-out*." In the former case an excavation is made in the *west* wall of the cellar, on a level with the floor of it, and carried underground until a sufficient distance is reached to provide comfortable room for those who propose to occupy the cave. The overhanging earth must be supported by heavy timbers and then arched over with masonry of brick or stone. This extra precaution concerning the roof is necessary to provide

against any serious damage to it by falling timbers or heavy masses of debris.

The excavation is made into the *west* wall because the storm, always approaching from the west, will carry the debris away from that side. But even this favorable position does not preclude the probability of debris being thrown upon the cave by the whirling currents of the vortex. The extra care bestowed upon the roof is money and time well expended.

Careful attention should be given to ventilation and drainage, and to making the retreat in every way as convenient and comfortable as possible. The extent to which this suggestion can be complied with will depend upon the pecuniary ability of the person concerned.

### THE "DUG-OUT."

20. The *"dug-out"* is a tornado cave not necessarily connected with any building. The results to be secured are the same as those derived from the use of the *cellar-cave.*

All houses are not supplied with cellars, and moreover a tornado cave is sometimes required where buildings are not located, or at least so situated as to make connection with the cave impracticable.

If the "dug-out" is placed near any building, it should be to the *west* of it, for reasons given in paragraph No. 19.

If buildings or other high objects are not to be considered, then the cave can be located at any point where the ground is dry and easily worked. The entrance and exit to the cave should be located *east* of the main portion of it, connecting

THE TORNADO OF MORGAN, SANGAMON, LOGAN AND DE WITT COUNTIES, ILLINOIS, MAY 18, 1883; 15 PERSONS KILLED, 20 WOUNDED, 63 BUILDINGS DESTROYED AND 120 ANIMALS KILLED; LOSS, $200,000.

therewith by a tunnel or chamber. Where it is practicable these two openings should be independent of each other, so that if by any chance one was barricaded with debris, the other would be available for urgent use.

To accomplish this result one opening may be placed at the east end and the other on either the north or south side, but as near the east end as practicable.

The roof of the cave should always be arched, because offering more resistance to the force of the wind and falling debris, than a plane surface. The ceiling of the roof should be at least three feet below the earth resting upon it, and the earth covering should have about the same depth or even more. This loose dirt must be well packed and sodded, thus preventing it from being washed away by the rains.

Every precaution should be taken to prevent decay of the materials used in constructing the cave.

The entrance and exit doors should be made of heavy timbers and well strapped with iron.

During the tornado season, the cave should be in constant readiness for use, at any moment of night or day.

As the necessity may arise for occupying the cave temporarily while the house is being repaired, it will not be amiss to construct the cave, where practicable, with this end in view.

During the season of year when tornadoes are not likely to occur, the cave may be turned to practical account for the storage and safe keeping of many articles.

It could be very successfully made to answer the purpose of an out-door cellar.

## EXPENSE OF CONSTRUCTION.

21. The cost of a properly constructed tornado cave, including material and labor, will range according to the quality, strength and character of the material with which it is built, together with the price of labor, from $150.00 to $350.00. Such a cave will comfortably accommodate ten grown persons.

Some caves have been constructed at a cost of $500.00, being provided with many comforts and conveniences that would permit their occupancy for sometime if necessary.

It is important to state that the above figures are based upon the actual payment of money for labor. Where necessary, economy can be exercised in this respect by the party concerned, performing much of the labor himself.

22. *The tornado cave is the only means of securing absolute protection to life.* This fact should be indelibly impressed upon the mind of every person living in a section of country liable to the occurrence of tornadoes. No building, however constructed, is proof against the terrific force of the tornado's vortex. It is probably safe to say that nothing which man can build, if it rises above the surface of the ground, can resist the enormous force of a tornado.

## THE WIND'S FORCE.

23. The rush of air into the tornado's vortex, and therefore the violence of the winds, depends upon the difference in barometric pressure between the inside and outside of the storm. This difference has been observed to be nearly three inches and may be very much more, for observations have never been made in the center of the vortex.

A gradient of three (3) inches, however will give a velocity of 323 miles per hour, which will exert a pressure of about 260 pounds per square foot against a surface exposed at right angles to the direction of the wind.

Air moving with a velocity of 100 miles per hour against a building exposing a plane surface of 1,000 square feet will exert a pressure upon that structure of 26,000 pounds, or 13½ tons. With a velocity of 500 miles per hour, the pressure would be increased to about 980,000 pounds, or 490 tons.

This enormous pressure is considerably less than that which would result in the case of a complete vacuum in the tornado's vortex.

Under such circumstances the air rushing into the vortex would move at the rate of about 1,400 feet per second, which would be nearly equivalent to a velocity of 1,000 miles per hour. The pressure upon each square foot of surface exposed to such a velocity would be about 28,000 pounds, and upon the whole building (1,000 square feet), 2,800,000 pounds, or 1,400 tons.

The force referred to in these computations is acting only in right lines, but when it is realized that in the actual tornado the forces brought into play are exerted both in right and curved lines, the destructive power is seen to be almost incalculable in fury and energy.

The explosive force of confined air in a tornado is enormously great and frequently it is to this energy, rather than to the direct force of the wind, that the destruction of buildings is due.

As a tornado cloud passes over a building, if the air within

is confined by closed doors and windows and can not readily escape, the explosive force, due to a very great difference in tension between the air inside and outside of the building, bursts asunder the walls and throws the roof upward to a considerable distance. Eye-witnesses state that roofs under such circumstances have been thrown a distance of 500 feet.

Under such conditions cellar doors have been blown away from their fastenings, in the face of a strong wind coming directly against them, and corks have been blown out of empty bottles by the sudden expansion of the air within them. Many almost incredible instances of extraordinary violence, by the explosive force of a tornado can be given, but want of space forbids more than this general reference to such manifestations of the tornado's power.

A building may sometimes be saved from destruction, if not in the immediate path of the tornado, by opening all the doors and windows to prevent the sudden expansion of the the inclosed air.

Enough has been said to show that it is perfect folly to think of protecting life by resort to any structure that rises above the surface of the ground. The under-ground retreat, however humble, is the only safeguard against the fury of tornado.

Let all people who reside in exposed sections of country where tornadoes are likely to occur build tornado caves and thus find relief from all anxiety, and safety from all danger, upon the approach of the most dreadful of storms.

When the author first advised the building of tornado caves in 1879 as a means of saving life people were incredulous

and the Press, in some instances, rather ridiculed the idea saying, that at the least, it was rather an undignified thing for man, the grandest and greatest of all creation to burrow in the ground at the sight of a dark cloud; that there must be some other means of escape, the preparation for which would certainly reflect more credit upon the ingenuity of man. There is nothing to prevent any man from attempting the construction of a tornado-proof building or cage, something that will be above ground and possess both strength and architectural beauty, but I venture to assert that the man who thus essays to grapple with the tornado on its "own ground" will not be one of the *genus homo* who has actually experienced a genuine "twister."

The expense of such a structure would be very great while its practical value would be nothing, for it could not be made to withstand the violence of the tornado. There is nothing discreditable or undignified in a man seeking protection from the elements in an under-ground retreat when it is conclusively shown that no other shelter will suffice. It is certainly not sensible in a man of good judgment and reason to defy the elements and endanger or sacrifice his life for some false and foolish sentiment.

I have personal knowledge of two cases, one in Michigan and the other in Missouri, where men deliberately faced the tornado and defied the winds, for they boasted that no dark cloud could make them "hunt their holes." Their mangled and discolored bodies paid the penalty of an insane recklessness. Such is the abject terror which possesses all alike after the experience of a tornado that hardy, brave men who have,

without flinching, faced the red-hot belchings of a score o batteries on the field of battle, will now, at the sight of a threatening cloud or the experience of a violent wind, mak a bold dash for places of safety.

The aversion to the tornado cave, which at first existed, has gradually given place to a feeling of confidence and satisfaction, because those who have had occasion to experience the importance and security of this means of protection are making it known for the benefit of others. Moreover, people are beginning to realize, in the most forcible manner, the inadequacy of any building that rises above the surface of the ground. Where, several years ago a "dug-out" could be found now and then in the tornado regions, hundreds are ready for use to-day. Experience is a dear, but a most effective instructor.

### TORNADO LIFE INSURANCE.

Before closing this subject, I deem it advisable to invite attention to another proposition concerning the protection of life, which I have not before referred to in previous writings on the subject of tornadoes.

I refer to life insurance. The risk to life and limb in the case of tornadoes would naturally bring business of this character under the methods which govern accident insurance companies, and this is where, in my opinion, the writing of such insurance belongs.

Insurance of this character is a perfectly legitimate business and can be conducted as safely and profitably as hazards against life and limb on rail or water.

The sinking of a steamship or the wreck of a railroad train may involve the death and the maiming of hundreds, the tornado can not do more, although the wounds and sufferings are sometimes more shocking. The loss is not necessarily greater in one case than in the other, in proportion to the risk assumed, and the safety of the company on the one hand, together with the certain and adequate return to the insured on the other, makes the proposed line of business, one that should commend itself to all concerned.

While the tornado cave offers absolute security to life, if the opportunity to enjoy its protection is available, there will always be hundreds of cases where people, from the exigencies of business or similar reasons, are unable to secure such measures of safety, and must take their *chances* during the raging of the elements. Such people should carry tornado accident insurance and enjoy the benefit of reasonable protection under all cirumstances. Even those who have the opportunity of using a tornado cave may fail to get there at the last moment and their possession, under such circumstances, of an accident policy would make life and limb doubly sure, and the sufferings and privations of an injury more easily borne.

### PROTECTION TO PROPERTY.

No building can be made sufficiently large, strong, high or low, or of any material whatever, that will resist the force of the tornado's vortex. There is no changing the path of the tornado by the employment of explosives or any artificial barrier.

It is idle to contemplate the dispersion of the cloud by the use of any electrical or other contrivance. The tornado has come to stay and will remain, as long as the earth has an atmosphere and the sun shines upon it.

Construct all buildings as would be done without the knowledge of the tornado, but protect them, not by a "tornado lightning rod" which is supposed, in some mysterious and effective manner, to draw off safely the fierce venom of the storm, or by the use of a "tornado bomb" to scatter the wild fury of the funnel-shaped cloud, but by the employment of some reasonable and efficacious means that will secure an adequate return for the loss sustained.

It is idle prattle to talk about the ultimate disappearance of the tornado with the rapid development of the country.

The building of railroads, the planting of forests and the cultivation of land are all evidences of material prosperity, but are not in the least conducive to the disappearance of conditions favorable to the development of tornadoes. On the contrary, they provide greater opportunities for exhibitions of their violence.

From a business view, and as affecting the question of life and property the tornado must be considered as one of nature's agencies for destruction, which must forever be fortified against.

Like fire and flood, and yet more dreadful, protection against such forces must be accomplished by organized capital where the safety of one is assured by the legitimate and successful co-operation of many.

All property can be successfully protected, important

papers, jewels, silver and gold plate, and other valuable articles of small size may be preserved in the tornado cave during a storm. Other property must be insured and it is the only means of safety that is worth considering for the purpose.

The author strongly advocated this method of protection during his tornado investigations in the West in 1879, being among the first to suggest and encourage the proposition, both verbally and through the Press; also in a pamphlet entitled, "The Characteristics of Tornadoes and the Means of Protection to Life and Property," published in June of that year, under the direction of the Chief Signal Officer of the Army.

When the matter was first submitted to some of the leading fire companies as a legitimate and profitable source of business, it was dismissed at once as impracticable, by others as something they might see fit to consider in the near future while still others (a very few) courageously accepted the responsibility and offered their assistance to suffering humanity.

Of course, the risks were rather unusual, and the methods of conducting the business successfully, yet to be formulated.

Caution and mature consideration were necessary, and commendable on the part of those who entered the business, for such precaution gave the most positive assurance to those who needed protection that all losses would be promptly paid.

As yet it is not altogether clear, to all persons concerned, that tornado insurance can be made successful for both the

policy holders and the companies, but the large increase in the business of writing tornado risks (over $100,000,000 since 1881) and acceptance of the inevitable by the largest and most influential companies in the country, shows that obstacles to success in this very important public measure are rapidly disappearing, and that abundant and unquestionable protection will be afforded (within the reach of all) to those who live in the tornado regions of this country.

I am not writing as an insurance expert, but as one who has labored earnestly and industriously for years with the tornado problem, the practical solution of which, must involve, with other things, a reasonable and adequate means of protection to life and property. This is a living question and appeals, as a matter of course, to the common sense of all classes of people. Those who suffer from these terrible visitations are crying aloud for protection, for indemnification from loss, a loss that is more complete and irreparable than that which results from almost any other power known to man.

Such necessities being known to exist the most effective remedies must be sought and applied. Again I repeat, *build tornado caves and insure both life and property.*

## TORNADO REGIONS.

There is not a State east of the 100th meridian that has escaped the violence of a tornado. Every State within this region is subject to the occurrence of violent storms, but some much more than others. I have elsewhere referred to the regions of maximum tornado frequency and to those

States in which the greatest destruction has occurred, or is likely to occur. A consideration of the geographical distribution of tornadoes for nearly one hundred years settles, beyond all question, the location of the great tornado region of this country as embracing the lower Missouri, central Mississippi and Ohio Valleys.

There are portions of each State, so far as present records are concerned, that have never been visited by tornadoes. Why they have thus been spared, if spared at all, is not altogether clear. The absence of tracks upon the chart (see frontispiece) may be due to failure of reports rather than to some special exemption of that region from such phenomena.

West Virginia has usually been pointed out as a State free from the ravages of violent storms, because charts of storm distribution failed to locate any such phenomena within her boundaries. But now that the Signal Service has established tornado reporting stations at different points within that State, the map is no longer free from tornado symbols for West Virginia.

A similar condition of things obtained for a time regarding Dakota and many people who were contemplating removal to that great agricultural region loudly proclaimed that the territory was exempt from insects, floods and tornadoes. But unfortunately their blissful ignorance of the true situation was rudely dispelled when, after a few months residence, the winds made havoc with life, crops, stock and buildings. As the territory settled up tornado reporting stations were opened by the Signal Service, and the previously clean surface on the chart for Dakota, became rather thickly dotted,

especially the eastern portion of the territory, with tornado symbols.

The tornadoes have gamboled there (Dakota) for ages, but no official record could be made of the fact owing to the lack of reports.

We cannot apply this method of reasoning to explain the absence of tornadoes in the States and Territories west of Dakota, which for indubitable meteorological reasons that have been very fully set forth in the earlier pages of this book, are located on the eastern border of the tornado belt.

The eastern portion of Colorado is within the tornado belt, and although we have but occasional reports of tornadoes from that region, it is evident that all the storms are not reported owing to the want of observers to record them and furnish the necessary information. The country is yet new and very sparsely settled. Proceding southward we find Indian Territory and the whole of Texas, except the extreme western portion, embraced in the tornado belt.

Violent local storms have been reported in the extreme eastern portions of Wyoming, Montana and New Mexico, but the data, in most cases, was too meagre to satisfactorily determine the true character of the storm. It is quite probable that tornadoes may occur over these plains, which are considerably east of the mountains.

In the western portion of the United States the region of country believed to be exempt from tornadoes includes the following States and Territories: Montana, Wyoming, Western Colorado, New Mexico, Arizona, Utah, Nevada, Idaho, California, Oregon and Washington Territory.

In the eastern portion of the United States tornadoes rapidly decrease in frequency as we approach the Atlantic coast, and entirely disappear within about fifty miles of it. It may occur that a tornado starting in the interior of one of the coast States will continue its course until the ocean is reached, but tornadoes do not appear to originate on the coast.

This peculiarity is ascribed to the fact that the conditions of temperature and moisture are not favorable to the development of the unstable state of the atmosphere.

There is naturally a very equable relation of these elements on the coast and therefore the normal condition of the atmosphere is not subject to a rapid decrease of temperature with increase of altitude, which would readily induce the unstable state.

The warm moist winds of the Gulf Stream do not encounter the cold dry winds of the interior at the coast, but far inland, owing to the passage of the "Lows" eastward too far to the north.

It is important to note in this connection that water-spouts in the Atlantic do not, as a rule, form near the coast, but on or beyond the eastern edge of the Gulf Stream. The conditions of temperature and moisture are not altogether favorable to the development of the unstable state of the atmosphere between the Gulf Stream and the coast.

There is a reversal of this state of things on the west coast of Africa, where the warm trade winds from the northern part of that country run under the comparatively cold air of the upper strata moving eastward from over the Atlantic,

which condition gives rise to a very rapid decrease of temperature with increase of altitude, very nearly, if not quite, equal to that which produces the unstable state in unsaturated air. But in this case the warm air comes from the land and the cold air from the water, while the reverse obtains on the Atlantic coast. Moreover, the excessive dryness of the air which comes from northern Africa is such that only small whirlwinds without spouts, usually called "white squalls" or "bull's-eye squalls," can form.

What the Atlantic coast fails to obtain in the way of tornadoes is bountifully supplied from that inexhaustible source of storm energy, the West India cyclones.

Every year, from August to November, the Atlantic and Gulf coasts are ravaged by these violent and destructive storms.

The Florida Peninsula, south of paralled 29° N. is exempt from tornadoes, but it does not escape the cyclones, that every autumn sweep over that region with considerable violence.

In connection with the question of the geographical distribution of tornadoes, a chart of the United States acccompanies this book (see frontispiece) which exhibits the region of no tornadoes, tornado belt, and the region of maximum tornado occurrence in each State within the belt.

This graphic illustration of tornado distribution, while instructive in other respects, will show in every State, the region within it, where tornadoes have most frequently occurred in the past, and where they are most likely to occur in the future.

## THE NECESSITY FOR TORNADO INSURANCE.

During the past five years the waste by fires in the United States has averaged $104,000,000 annually, an amount equal to double the annual interest paid on the national debt. While this amount of destruction to property is really enormous, yet it is less than one half the loss occasioned by atmospheric changes, which give rise to storms, floods, droughts, and frosts, a source and extent of destruction which must appeal to the minds of all thinking men with overwhelming force. What an extraordinary drain upon the resorces of this country. What a vast portion of the values produced must go to pay this tremendous tax. But the burden is borne, and that to, by a portion of the population much less able to contend with misfortune than the majority of those who suffer loss by fire.

There is no question as to the great moral and pecuniary benefit arising from fire nisurance. A man whose property, unprotected by any indemnification against loss, is swept away in smoke and ashes, or by storm and flood, becomes a non-producer, and he, together with all those dependent upon him, a charge upon the public. He is helpless and perhaps never recovers from the ill fortune which has so suddenly befallen him.

On the contrary, if this adversity is met by a prompt return of a reasonable percentage of the loss, the benefit is not alone to the individual, but to the State.

There has been, to be sure, an actual destruction of a certain amount of wealth, but there is still left a factor (the property owner) who, under certain conditions, is capable

of reproducing, not that which was actually lost, but its equivalent.

Another feature of this subject is the tax upon the individual to secure indemnification from loss. While this, to the minds of some, may seem an unnecessary assumption of a burden in anticipation of trouble which may never come, yet the mass of mankind think differently, as statistics show. Protection in any industry is necessary to its success, but protection, without cost to those protected, is impossible. What a man rightfully acquires belongs to him as his possession, whether he earns it in protecting others or in being protected by them.

But to return more closely to my subject. Are losses by atmospheric disturbances insurable risks? If so, why not form the proper organization to provide indemnification against such destruction?

Moral hazards and criminal hazards are impossible factors in storm insurance, while in fire insurance, incendiarism and carelessness constitute 90 per cent. of the risk. Such serious hazards can never affect the damage resulting from atmospheric disturbances.

There are strong points in favor of storm, flood, drought and frost insurance. But some insurance expert says, that the danger to successful business in this direction exists in the possibility of sweeping losses. There is no strength in this argument, for it vainly attempts to avoid a difficulty that besets every commercial enterprise, viz: the want of tact and brains to thoroughly appreciate its necessities and provide the means for meeting them, in the most practical and

profitable manner. "Where there is a will there is a way," is a trite saying, but it sometimes has peculiar force, especially in this instance.

Fire insurance is profitable and beneficial in spite of the great difficulties that arise from incendiarism and carelessness, which are hazards that cannot be successfully controlled.

Storm, drought and frost insurance, on the contrary, will encounter no such obstacle, the so-called damage from "sweeping loss" can be regulated by a proper distribution of risks, coupled with a careful consideration of rates.

Strong and earnest efforts should be made by public-spirited, influential and energetic business men to consider this question, and to organize for the purpose of extending the benefits of a wisely conducted business to the people who suffer so severely from the forces of nature. The Press of the country will do well to agitate this matter. They are foremost in every good work, and the weight of their influence in this case would doubtless secure much benefit to the farmer and small property owner. While profitable to the company, this kind of insurance can be made extremely beneficial to both the individual and the State. It may be practicable for some of the powerful fire companies to extend the limits of their business so as to include storm, flood, drought and frost risks.

There is not one of these hazards but what can be approached in a way to determine the laws governing its occurrence and distribution, and to obtain statistics from which methods of business can be formulated.

Tornado risks have already been accepted as insurable, and there is essentially no dividing line between such hazards and those of hail, flood, drought and frost.

Tornadoes, hailstorms, thunderstorms and cyclones have been considered in this connection under the one term, *storms*.

**EVIDENCE OF THE GREAT POWER OF TORNADOES.**

In concluding this brief compendium of facts, statistics and suggestions. I will submit some additional information as to the great loss occasioned by tornadoes in particular, and instances of the extraordinary violence of the wind in the tornado's vortex.

At Natchez, Mississippi, May 7, 1840, 317 people were killed, 109 wounded, and $1,260,000 worth of property destroyed. Sheathing was carried 20 miles and windows 30 miles.

In Adams Co., Mississippi, June 16, 1842, 500 people were killed, many more wounded, and $2,000,000 worth of property destroyed.

On June 3, 1860, the towns of Camanche, Iowa, and Albany, Illinois, were destroyed, nearly 100 people killed, several hundred wounded, and about $1,000,000 worth of property destroyed.

June 29, 1865, the town of Viroqua, Wisconsin, was destroyed, 17 people killed and 150 wounded.

In Wisconsin, on May 23, 1878, the "Mineral Point tornado," which extended nearly across the State, killed 30 people, wounded several hundred and destroyed about $1,000,000 worth of property.

April 16, 1879, at Wallingford, Connecticut, 34 people were killed, 28 wounded, and 100 buildings destroyed.

April 18, 1880, in Barry, Stone, Webster and Christian counties, Missouri, 110 people were killed, 600 wounded, and over $1,000,000 worth of property destroyed. At Marshfield, one of the towns in the line of this storm, 60 people were killed outright, 32 died from wounds, 8 had limbs amputated, many were made cripples for life and hundreds were variously injured. The wounds were very difficult to heal and almost impossible to cleanse. In many cases several days were required to clean them, in anything like a satisfactory manner. Frequently, after every effort had failed, the fine particles of gravel, sand and dirt were only removed by slough, so firmly were they driven into the tissues surrounding the cuts. Even the hair and skin, where there was no solution of continuity, were literally filled with these fine particles.

A board four inches wide and one inch thick was driven, by the wind, through a live oak sapling four inches in diameter.

A shingle, but-end foremost, struck an inch-plank diagonally and passed *through* it, instead of *glancing* off. A rock weighing three-fourths of a ton and partially embedded in the ground was rolled from its bed.

Heavy timbers were carried distances of from 12 to 20 miles. Letters and papers were actually carried a distance of 102 miles. The roof of a house was carried, entire, a distance of 12 miles.

Men who held to bushes and trees were literally whipped

to death. A house-log was blown, end foremost, three feet into the ground, after being carried about one mile. Corn-stalks were driven into hard oak trees with such force that they could not be wholly withdrawn without first splitting the trees.

The *southwest* corner of a heavy foundation was blown entirely out of the ground. A tree, one foot in diameter at the butt, was carried a distance of eighteen miles.

In several cases the fringe or trimmings upon dresses and cloaks was whipped off by the wind, the stitches being taken out as neatly as though done by hand.

Fowls were completely divested of feathers and in some cases were torn limb from limb.

The largest trees were torn up by the roots and blown back in the direction from which the tornado came, some of them having tons of dirt and rocks clinging to the roots, and leaving great holes in the ground.

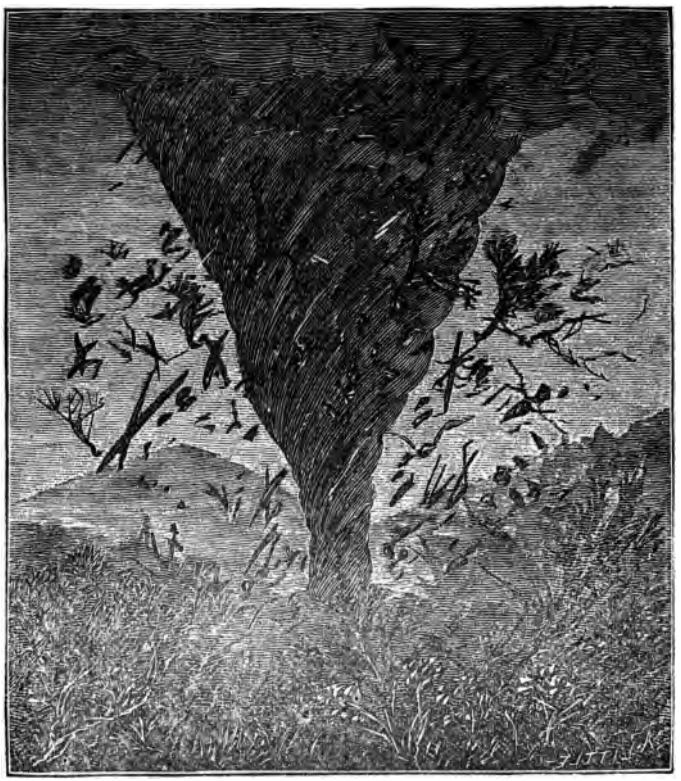
An ice-chest weighing 800 lbs. was carried several miles. A well thirty-nine feet deep and half full of water was completely emptied by the force of the wind.

An eight-penny nail was driven half its length into an oak tree, twenty feet above the ground.

Small pine splinters were driven into the bodies of trees so that they could not be pulled out.

A hog was taken up and thrown down with such force that its legs were driven into the hard ground up to its body.

A horse was carried through the air half a mile without being killed, and another was blown a distance of 200 yards and cut in twain.



THE TORNADO OF ERCILDOUN, PENNSYLVANIA, JULY 1ST, 1877; 5 PERSONS KILLED, 50 WOUNDED 60 BUILDINGS DESTOYED AND 40 ACRES OF HEAVY TIMBER DEMOLISHED.

At Savoy, Texas, May 28th, 1880, 40 people were killed, 33 wounded and 60 buildings destroyed.

New Ulm, Minnesota, July 15, 1881, 11 people were killed, 65 wounded and 300 buildings destoyed.

In Grinnel, Poweshiek and Malcolm Co's, Iowa, June 17, 1882, 150 people killed, 300 wounded and 250 buildings destoyed; loss over $1,000,000.

In Copiah, Simpson, Newton, Lauderdale and Kemper Co's, Mississippi, April 22, 1883, 51 people killed, 200 wounded and over 100 buildings destroyed.

In Henry and Saline Co's, Missouri, April 18, 1882, 8 people killed, 150 wounded and 55 buildings destroyed.

At Racine, Wisconsin, May 18, 1883, 16 people killed, 100 wounded and 52 buildings destroyed.

In Dodge and Olmstead Co's, Minnesota, August 21, 1883, 56 people killed, 80 wounded and 400 buildings destroyed.

In Izard, Sharp and Clay Co's, Ark., November 21, 1883, 26 people killed, 80 wounded and 60 buildings destroyed.

On February 19, 1884, in the States of Virginia, North Carolina, South Carolina, Georgia, Alabama, Mississippi, Tennessee, Kentucky, Illinois and Indiana, over 60 tornadoes occurred between 10 a. m. and midnight. 800 people were killed, 2,500 wounded, about 15,000 left homeless and over 10,000 buildings destroyed, together with hundreds of cattle, horses, hogs and other domestic animals.

At Jamestown, Ohio, April 27, 1884, 6 people killed, 15 wounded and over 300 buildings destroyed.

In Hennepin, Ramsey and Washington Co's, Minnesota, and St. Croix, Polk, Barron, Chippewa and Price Co's,

Wisconsin, September 9, 1884, 6 people killed, 75 wounded and 305 buildings destroyed; loss $4,000,000.

In Camden Co., New Jersey, August 3, 1885, 6 people killed, 100 wounded and 500 buildings destroyed.

In St. Lawrence Co., New York, August 12, 1885, 2 people killed, 10 wounded and 106 buildings destroyed.

In Fayette Co., Ohio, September 8, 1885, 6 people killed 107 wounded and 300 buildings destroyed; loss over $500,000.

In Benton and Stearns Co., Minnesota, April 14th, 1886, 74 people killed, 136 wounded and 138 buildings destroyed; loss over $400,000.

In Huron Co., Ohio, May 12, 1886, 30 people killed, several hundred wounded and 95 buildings destroyed; loss over $300,000.

At Prescott, Kansas, April 21, 1887, 20 people killed, 237 wounded and 330 buildings destroyed; loss over $1,000,000.

At Mt. Vernon, Illinois, February 19, 1888, 22 people killed, about 130 wounded and over 100 buildings destroyed; loss over $250,000.

Ercildoun, Pennsylvania, July 1, 1877, 5 people killed, 50 wounded, 60 buildings destroyed, and 40 acres of heavy timber uprooted and twisted into confused and shapeless masses. Pillars of brick, weighing several tons, were rolled out of their places near the top of the Seminary building and buried in the earth to a considerable depth.

A cow was blown over a hedge 20 feet high and killed. Several school books were carried distances of from four to ten miles and safely deposited near farm houses in the surrounding country.

Letters were carried distances of ten and fifteen miles.

Three carriages, within the same building, had their wheels deposited at different points of the compass, more than 100 yards distant from the building and from each other. The spokes and axles in most cases could not be found, only the fellies and tires of the wheel remaining.

In several instances roofing material was interwoven with the branches of trees and wound around the same two or three times.

A large chestnut tree was entirely stripped of foliage and small limbs, but not overthrown.

A large apple tree was uprooted and carried several hundred yards, with many hundred pounds of earth attached to the roots.

Over one hundred quilts and blankets from the Seminary were lodged in the neighboring forests, torn into shreds.

Growing potatoes in the fields were entirely divested of their green tops, the bare ground alone remaining.

Many bushels of grain were sown over acres and acres of ground.

Several hogs were found after the storm completely covered with dirt and almost unrecognizable; they seemed to breathe with the greatest difficulty and one of them soon died.

At and near Providence, R. I., September 8, 1869, says an eye witness:

"Mighty trees bent and bowed before the tempest, some of them being torn up by the roots while others were snapped off like rotten twigs."

"Boards, bricks, shingles, broken boughs, portions of

gates and fences, shutters, signs, and fragments of all kinds filled the air. Massive buildings rocked like toys, roofs of tons in weight were lifted and carried rods away, or torn into minute pieces. Huge strips of tin and metal were torn from places where they had been securely nailed, and blown like sheets of paper for long distances. Steeples rocked and fell; huge buildings were crushed in like egg shells; vessels were swept like chips upon the shore; dwellings were overthrown, and carriages blown along the street like feathers."

Concerning this remarkable and violent storm the following verses are extracted from a ballad by Oliver Wendell Holmes:

"Lord! how the ponds and rivers boiled,
And how the shingles rattled!
And oaks were scattered on the ground,
As if the Titans battled:
And all above was in a howl,
And all below a clatter,
The earth was like a frying pan,
Or some such hissing matter.

"It chanced to be our washing day,
And all our things were drying;
The storm came roaring through the lines,
And set them all a flying;
I saw the shirts and petticoats
Go riding off like witches;
I lost, ah! bitterly I wept,
I lost my Sunday breeches!

"I saw them straddling through the air,
Alas! too late to win them;
I saw them chase the clouds, as if
The Devil had been in them;
They were my darlings and my pride,
My boyhood's only riches,
"Farewell, Farewell," I faintly cried,—
"My breeches! O my breeches!

"That night I saw them in my dreams,
How changed from what I knew them!
The dews had steeped their faded threads
The winds had whistled through them;
I saw the wide and ghastly rents
Where demon claws had tore them;
A hole was in their amplest part,
As if an imp had wore them."

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Jefferson County, Iowa, April 21, 1878. Eye witnesses who were just out of the range of the storm described the cloud as whirling, funnel-shaped, dipping and rising alternately, and forming half circles north and south of the central track of the storm. Every thing in the path of the tornado was crushed and twisted beyond all semblance to its natural condition.

The following incident shows the peculiar action of the wind in the tornado's vortex:

A father and son were in the kitchen on the west side of the main building. The door on the south side of the former was blown open and both were carried out of the house by the force of the wind. The son was blown around the southwest corner, north thirty feet over a fence, set down and soon picked up again by the wind, and carried back between the same fence-posts to the corner of the house, near where the father was *left* by the wind.

A barrel of corn-cobs standing on the west side of a partition was blown south six feet, then east through a door, then north six feet on the opposite side of the partition, where it was left standing without removing the contents.

A piece of barn timber 8x8 inches and ten feet long was carried to the northeast about three miles, and buried nearly half its length in the earth.

An oak timber 6x14 inches and 22 feet in length was carried northeast about 200 yards and split for nearly ten feet.

A wagon wheel and part of the axle was blown a distance of one-and-a-half miles. Papers were carried a distance of ten miles.

Buena Vista, Crawford and Sac Co's, Iowa, April 21, 1878, 5 people killed and 50 wounded. Says an eye witness: "It is utterly impossible to give even the faintest idea of the tremendous power of the tornado. Thousands of pieces from various buildings were blown northeastward several hundred rods and driven into the ground. The siding and light lumber were split and pounded into kindling wood. Trees were torn up by the roots and their tops whipped into shreds. The whole scene was one of utter destruction and desolation."

A boy thirteen years old was carried three-fourths of a mile and thrown to the ground, bruised, stunned, bleeding and stripped of clothing.

Wagon wheels were stripped of spokes and fellies, leaving nothing but the hubs.

A house 20x40 feet and two-and-a-half stories in height was moved bodily a distance of fifty feet to the northeast.

The track of the storm was strewn with dead fowls stripped of feathers, heavy timbers, dead hogs, cattle and horses, clothing, bedding, broken furniture and farm machinery, stoves, dishes and every article of household and farm use.

A small boy was carried 300 feet and struck by a piece of flooring which passed entirely through his body. He lived several hours, until the board was extracted, when death occurred in a few minutes.

A one-and-a-half story house, 16x26 feet and well built was carried 20 feet into the air, and dropped 300 feet from where it stood. After reaching the ground it was "whirled and twisted into a million pieces." The building contained four people who were terribly mangled, all of whom died within an hour after being removed from the wreck. A few hours before a happy, united family, now swept from the earth, both life and property, under the most awful circumstances. Neighbors sickened and fainted at the sight, and some were paralyzed with fear at the dreadful swiftness and completeness of the destruction.

A sewing machine was carried two miles. A horse had its legs broken; another was carried half a mile and a stick driven through one of its legs by the force of the wind.

A large country school-house was whirled 40 feet into the air and carried a distance 1,000 feet where the wreck was scattered in all directions.

Fourteen pigs were carried together a distance of one mile and dropped without injury.

A boy was driving six cows and all were carried into the air, the boy was blown nearly a mile and severely injured, and the cows killed.

A corn-planter, weighing 150 pounds was carried 40 rods.

The forepart of a wagon eight rods. The large drive-wheel of a reaper was carried 1,000 feet; sides of pork from 600 to

800 feet, and a portion of a school-house door three miles, it being recognized by the hinges.

An eye witness states:

"That people should deem some of these occurrences marvelous and impossible, we can readily believe, for had we not visited the path of the storm and actually stepped off the distances we should have deemed the narrative due to excitement and over-estimate."

Another eye witness writes as follows:

"It was awful to see it coming straight toward us, and we did not know which way to go; but when it got within a a mile west of us it turned and went to the northeast a mile and a half, but the force of it blew down seven buildings in town. I saw lumber, hogs, horses, chickens, wagons, threshing machines, cows, quilts, almost everything you could think of, flying in the air, a hundred feet high. We find ducks, chickens, and all kinds of birds, with every feather plucked, some with their heads off, and all so covered with mud that you could not tell what they were except by their bills. Buildings were lifted in the air and twisted to pieces, and all that we could find of them were little sticks driven into the ground, so hard that you could not pull them out. It cut just such capers as the tornado did at Camanche. It took the tires off wagon wheels and tied them in knots, and broke the spokes off close to the hubs; it carried a woman high in the air and let her down sixty rods from where it picked her up, unhurt. The sky was clear in the west, and all there was in sight was that tunnel-shaped whirler, coming directly toward us. It was in sight for thirty miles, and we could hear it when it did not look larger than a man."

Another eye witness writes as follows:

"I was out buggy-riding at the lake (Wall Lake, Sac Co.),

' the storm coming and ran my horses three miles to get of its course. When I thought I was safe I stopped, I watched the thing go across the prairie. I saw it pick seven houses and whirl them away. I saw it catch up ee cattle and carry them off as if they were so many ıws; one of them was found four miles away, and the er two have never been found. At one house it took up ıan, wife and three children, carried them out on the irie, scattered them far apart, but killed none of them."

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## CONCLUSION.

t is needless to continue the story. The harrowing de- s might be prolonged until volumes were written and n not concluded.

These verses aptly portray the dreadful scene of death and olation:

Beneath the terrible tempest's power,
She, like some frail and delicate flower,
Lay stricken in that awful hour,
The tornado-swept village.

Lay crushed and ruined, heap on heap,
Homes dashed in pieces by the sweep,
Of the fierce hurricane's frightful leap,
The tornado-swept village.

Weeping and wailing filled the air,
Sharp shrieks and agonizing prayer;
"Where is my darling, tell me where?"
In the tornado-swept village.

Alas, her darling never more,
Shall greet her on this earthly shore!
In one swift moment all was o'er,
In the tornado-swept village.

The long list, ever increasing, of destructive aerial meteors in this country, each with its tale of suffering, death and desolation has no parallel in the world.

Added to this fact appears the additional one, that the United States, or rather a certain portion of it, will forever suffer from these visitations, and as the country increases in wealth and population so will the direful results from these aerial monsters.

Nothing is gained by trying to conceal the truth. Such a course begets indifference and negligence, which must eventually result in great evil. On the contrary, spread abroad true information, instruct and encourage all who will seek the truth. Make them to know that nature's laws are not "past finding out," but that the principles underlying them are being rapidly discovered and the results of such research applied for the immediate benefit of mankind.

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